01 SOLID FUELS

Sources, winning, properties

13/03139 Coal deposits as promising sources of rare metals for alternative power and energy-efficient technologies

Seredin, V. V. *et al. Applied Geochemistry*, 2013, 31, 1–11.

This paper presents data on widespread abnormal accumulations in coal deposits of some rare metal(loid)s (Ge, Ga, Se, Li and REE + Y), which play a key role in energy-efficient technologies and alternative power development. It is shown that enrichment of these metal(loid)s may occur in coal seams in host- and basement-rocks of coal basins at comparable concentrations to those in conventional ores. Genesis of high concentrations of the rare metal(loid)s and their modes of occurrence in coal basins are reviewed. Moreover, utilization prospects of these metal(loid)s as by-product coal deposits are evaluated. The extraction of these metal(loid) resources during coal exploitation and utilization would not only increase beneficial use of coal deposits themselves but also promote further movement on the 'green road'.

13/03140 Data-constrained modelling of an anthracite coal physical structure with multi-spectrum synchrotron X-ray CT

Wang, H. P. *et al. Fuel*, 2013, 106, 219–225.

A data-constrained modelling (DCM) approach with multi-spectrum synchrotron X-ray CT has been used to characterize the physical structure of Yangquan coal sample. Three sets of X-ray CT data have been acquired with monochromatic beam energies at 14, 18, and 30 keV respectively. A DCM approach is used to derive compositional volume fractions on each voxel, by minimizing the differences between the expected and CT reconstructed absorption coefficients with a non-linear optimization algorithm. Voxel-based 3D-compositional maps are generated with colours and intensities representing compositions and volume fractions respectively. The results are relevant in quantitative modelling of coal-bed gas transportation and coal processing.

13/03141 Direct determination of total CO_2 uptake by coal: a new technique compared with the manometric method

Hol, S. *et al. Fuel*, 2013, 105, 192–205.

This paper reports a newly developed technique that directly measures total CO_2 uptake of millimetre-sized coal matrix cylinders, without the application of the equation of state (EoS) for CO_2 and without the need for swelling corrections or He-pycnometry. The technique makes use of a capsule composed of ductile metals (Au and In), pressure-fitted to the sample, which traps directly both adsorbed and free CO_2 taken up by the sample upon exposure to CO_2. The authors applied the method to samples of high volatile bituminous coal (Brzeszcze, Seam 364, Poland), saturated with CO_2 at a fixed pressure between 0 and 18 MPa at 40 °C, and, as a function of pressure, yielded a Langmuir-like CO_2 uptake curve (within a band less than 0.5 mmol g_{coal}^{-1}) with a maximum CO_2 content of 4.08 mmol g_{coal}^{-1} at 18 MPa CO_2 pressure. For comparison, manometric determinations were performed on a combined set of eight samples, also at 40 °C, which yielded a three-stage uptake curve showing lower uptake than the capsule-derived curve, showing 20–30% lower uptake at pressures above $\sim$9 MPa. Allowing for worst case errors, the differences in CO_2 uptake obtained using the two methods are attributed to (i) random errors and to uncertainties EoS in the manometric data set at low CO_2 pressures (3–9 MPa), and (ii) systematic errors, due to erroneous trapping of free CO_2, dominating in the capsule data set high CO_2 pressures (>9 MPa). The capsule method proved reliable at CO_2 pressures of 0–7 MPa, while at pressures higher than 8 or 9 MPa the manometric method was most reliable. Although improvement is needed to prevent erroneous trapping of free CO_2 at pressures above 9 MPa, this new encapsulation method has the potential to accurately determine the uptake of any adsorbate by any (swelling) adsorbent, e.g. CO_2 uptake by shale and clay caprocks and is suitable for assessment of the effects of small-scale lithological differences in CO_2 uptake. Use of the manometric method with sufficiently large samples, or the capsule method at $P < 9$ MPa, provides a reliable means of measuring the CO_2 uptake capacity, yielding errors that are less than the effects of *in situ* stress on sorption.

13/03142 Effect of the addition of waste sawdust on thermoplastic properties of a coal

Montiano, M. G. *et al. Fuel*, 2013, 106, 537–543.

Three different sawdusts obtained as wastes from the furniture and flooring industry were selected to study their influence on coal thermoplastic properties. A bituminous coal with a high-volatile matter content was chosen as base coal. To investigate the effect of reducing the oxygen content of the sawdusts upon the coal's properties, the sawdusts were heat treated to 250 °C. Blends of the coal with the three as-received and then heat-treated sawdusts were tested. In order to gain a better insight into the subject, the sawdusts were pyrolysed at 400 °C to determine the effect of the resulting char and bio-oil on the plastic properties of the base coal. The Gieseler curves corresponding to the coal–sawdust blends were calculated from the curves corresponding to the coal-char and coal-bio-oil blends. The errors obtained were in all six cases lower than the repeatability allowed by the ASTM standard for the Gieseler test. Considering that the effect of the additives is the sum of both chemical and physical effects, it was possible to evaluate the contribution of each of these to the reduction of coal fluidity. In all cases it was found that the physical effects were more important. The textural properties of the chars obtained at 400 °C from the biomass were found to be important for determining the influence of biomass on the coal fluidity.

13/03143 Production history matching to determine reservoir properties of important coal groups in the Upper Pottsville formation, Brookwood and Oak Grove fields, Black Warrior Basin, Alabama

Karacan, C. Ö. *Journal of Natural Gas Science and Engineering*, 2013, 10, 51–67.

The Black Warrior Basin of Alabama is one of the most important coal mining and coalbed methane production areas in the USA. Methane control efforts through degasification that started almost 25 years ago for the sole purpose of ensuring mining safety resulted in more than 5000 coalbed methane wells distributed within various fields throughout the basin. The wells are completed mostly in the Pratt, Mary Lee, and Black Creek coal groups of the Upper Pottsville formation and present a unique opportunity to understand methane reservoir properties of these coals and to improve their degasification performances. The Brookwood and Oak Grove fields in the Black Warrior Basin are probably two of the most important fields in the basin due to current longwall coal mining activities. In this work, methane and water productions of 92 vertical wellbores drilled, some completed 20 years ago, over a current large coal mine district located in these two fields, were analysed by history matching techniques. The boreholes were completed at the Mary Lee coal group, or at combinations of the Pratt, Mary Lee, and Black Creek groups. History matching models were prepared and performed according to properties of each coal group. Decline curve analyses showed that effective exponential decline rates of the wells were between 2% and 25% per year. Results of production history matching showed, although they varied by coal group, that pressure decreased as much as 80% to nearly 25 psi in some areas and resulted in corresponding decreases in methane content. Water saturation in coals decreased from 100% to between 20% and 80%, improving gas relative permeabilities to as much as 0.8. As a result of primary depletion, permeability of coal seams increased between 10 and 40% compared to their original permeability, which varied between 1 and 10 md depending on depth and coal seam. These results not only can be used for diagnostic and interpretation purposes, but can be used as parameter distributions in probabilistic simulations, as illustrated in the last section of this paper. They can also be used in conjunction with spatial modelling and geological considerations to calculate potential methane emissions in operating mines.

13/03144 Thallium in coal: analysis and environmental implications

Antón, M. A. L. *et al. Fuel*, 2013, 105, 13–18.

The ecotoxicological importance of thallium stems from its acute toxicity, the effects of which are as harmful to living organisms as those of lead and mercury. The main anthropogenic sources of thallium are the emissions from coal combustion processes, underlining the need to control this element in coal and coal by-products. Despite the threat posed by thallium, very little information has been published on its behaviour in coal-fired power plants or on its modes of occurrence in coal, its mobilization and its distribution. Although thallium is highly toxic, the environmental risk presented by this element in coal utilization have been studied to a much lesser degree than in the case of other toxic elements such as lead, cadmium or mercury. The present work addresses the issue of thallium in coal, focusing on its origin, modes of occurrence, the analytical methods commonly used for its determination and its behaviour during coal utilization for energy production.

Preparation

13/03145 Effects of microwave irradiation treatment on physicochemical characteristics of Chinese low-rank coals

Ge, L. *et al. Energy Conversion and Management*, 2013, 71, 84–91.

This study investigates the effects of microwave irradiation treatment on coal composition, pore structure, coal rank, function groups, and combustion characteristics of typical Chinese low-rank coals. Results showed that the upgrading process (microwave irradiation treatment) significantly reduced the coals' inherent moisture, and increased their calorific value and fixed carbon content. It was also found that the upgrading process generated micropores and increased pore volume and surface area of the coals. Results on the oxygen/carbon ratio parameter indicated that the low-rank coals were upgraded to high-rank coals after the upgrading process, which is in agreement with the findings from Fourier transform infrared spectroscopy. Unstable components in the coal were converted into stable components during the upgrading process. Thermo-gravimetric analysis showed that the combustion processes of upgraded coals were delayed toward the high-temperature region, the ignition and burnout temperatures increased, and the comprehensive combustion parameter decreased. Compared with raw brown coals, the upgraded coals exhibited weak combustion characteristics similar to bituminous coal. The changes in physico-chemical characteristics became more notable when processing temperature increased from 130 to 160 °C or the rank of raw brown coal was lower. Microwave irradiation treatment could be considered as an effective dewatering and upgrading process.

13/03146 Fluidized bed drying of Loy Yang brown coal with variation of temperature, relative humidity, fluidization velocity and formulation of its drying rate

Kim, H.-S. *et al. Fuel*, 2013, 105, 415–424.

The fluidized bed drying of Loy Yang coal, which is one of Australia's representative Victorian brown coals exhibiting a high moisture content (up to *ca.* 65 wt%, as-received base), using air as the bubbling gas was examined by varying temperature, relative humidity, and fluidization velocity at 40–80 °C, 0–40%, and 10.0–35.0 cm/s, respectively. The effects of the three variables on the drying rate and drying time were investigated. Higher temperature, lower relative humidity, and higher fluidization velocity were favourable for drying, i.e. they showed high drying rate. Drying rate was at a maximum immediately after the set drying temperature was attained; then, it decreased at a roughly constant rate, indicating a falling-rate drying period (constant-decrease drying period) and finally became zero. Drying rate could be described by a simple equation, $dw/dt = -k(1-X)^n$; therefore, it was a function of the drying rate constant k, drying fraction X, and drying rate order n. The drying rate order n could be taken as 0.25; it is independent of temperature, relative humidity or fluidization velocity. The drying rate constant k could be expressed as a function of temperature, relative humidity, fluidization velocity; within the limits of the experimental error, k was a linear function of each variable, and it increased with increasing temperature, decreasing relative humidity, and increasing fluidization velocity.

13/03147 Fuel reactor modelling in chemical-looping combustion of coal: 1. model formulation

Abad, A. *et al. Chemical Engineering Science*, 2013, 87, 277–293.

A fundamental part of the reliability of the chemical-looping combustion system when a solid fuel, such as coal, is fed to the reactor is based on the behaviour of the fuel reactor, which determines the conversion of the solid fuel. The objective of this work is to develop a model describing the fuel reactor in the chemical-looping combustion with coal (CLCC) process. The model is used to simulate the performance of the 1 MW_{th} CLCC rig built in the Technology University of Darmstadt. The fuel reactor is a fluidized bed working at high velocity regime, using ilmenite as oxygen carrier. The developed model is based on semi-empirical correlations, and considers the reactor fluid dynamics, the coal conversion and the reaction of the oxygen carrier with evolved gases from coal. The efficiency of a carbon separation system is also considered in order to analyse this parameter on the fuel reactor performance. The main outputs of the model are presented in this work, i.e. (1) the fluid dynamics structure of the reactor; (2) the axial profiles of gas composition and flows (volatiles, CO, H_2, CO_2 and H_2O); (3) the conversion of the oxygen carrier and char in the reactor; (4) the char concentration in the reactor; (5) the gas composition and solids flow in the upper reactor exit; and (6) the char flow to the air reactor. From these outputs the oxygen demand of the flue gases and the CO_2 capture efficiency are calculated. Simulations on the effect of the efficiency of the carbon separation system are presented. A highly efficient carbon separation system should be used to reach a high carbon capture value. Also incomplete combustion of gases is predicted in the fuel reactor, mainly from unconverted volatile matter. The model can be later used to obtain basic design parameters of the fuel reactor and optimize its operation.

13/03148 Fuel reactor modelling in chemical-looping combustion of coal: 2 – simulation and optimization

García-Labiano, F. *et al. Chemical Engineering Science*, 2013, 87, 173–182.

Chemical-looping combustion of coal (CLCC) is a promising process to carry out coal combustion with carbon capture. The process should be optimized in order to maximize the carbon capture and the combustion efficiency in the fuel reactor, which will depend on the reactor design and the operational conditions. In this work, a mathematical model of the fuel reactor is used to make predictions about the performance of the CLCC process and simulate the behaviour of the system over different operating conditions. The mathematical model considers the fluid dynamic characteristics of the fuel reactor, being a high-velocity fluidized bed reactor. It also considers the chemical processes happening inside the reactor, and the effect of a carbon separation system on the char conversion in the process. A sensitivity analysis of the effect of the efficiency of the carbon separation system, the solids inventory in the fuel reactor, the temperature in the fuel reactor, ratio of oxygen carrier to fuel, oxygen carrier reactivity, coal reactivity and coal particle on the carbon capture and combustion efficiency is carried out. Also the relevance of the water–gas shift reaction (WGS) is evaluated. The most relevant parameters affecting the carbon capture are the fuel reactor temperature and the efficiency of the carbon separation system, η_{CSS}. A value for η_{CSS} as high as 98% should be necessary to reach a carbon capture efficiency of 98.6% when the solids inventory was 1000 kg/MW_{th}. Regarding the combustion efficiency, to use highly reactive oxygen carrier materials are desirable. In any case, additional actions or a modified design for the fuel reactor should be implemented to reach complete combustion of coal.

13/03149 Kinetics of CO_2 gasification for coals of different ranks under oxy-combustion conditions

Gonzalo-Tirado, C. *et al. Combustion and Flame*, 2013, 160, (2), 411–416.

It is widely recognized that char-CO_2 gasification reactions present in oxy-fuel processes may considerably alter the overall reaction rates in comparison to those attained in conventional combustion. In this paper, the results of an experimental study on the gasification kinetics of three coals of different ranks (from anthracite to lignite) under realistic conditions in an entrained flow reactor are presented; the work included also devolatilization and char oxidation tests in the same experimental facility. A particle combustion model, based on apparent kinetics, was used to derive kinetic parameters for each reaction with coal chars. A clear gradation of the char reactivity towards both O_2 and CO_2 with the coal rank was found. The same models were used to assess the relevance of gasification in oxy-combustion conditions; gasification may account for as much as 20% of the overall char consumption rate in the combustion of a low rank coal at low O_2, high CO_2 concentrations and offset (and exceed) the loss in the oxidation rate due to the change in diffusivity. These results clearly indicate the need to carefully consider the inclusion of gasification in the simulation of coal-fired boilers depending on the operating conditions.

Transport, storage

13/03150 Numerical investigation and theoretical prediction of self-ignition characteristics of coarse coal stockpiles

Zhu, H.-q. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 236–244.

Spontaneous combustion of coarse coal stockpiles in temporary coal storage yards was investigated numerically using COMSOL Multiphysics software. The main purposes of the numerical investigation were to identify the self-ignition characteristics of coarse coal stockpiles and formulate a theoretical model to predict the self-ignition time and locations of coarse coal piles. A mathematical model for self-ignition of coarse coal piles was developed and the process of spontaneous ignition of coarse coal stockpiles was simulated. The kinetic data of low-temperature oxidation reaction was obtained from the laboratory-scale experiments with bituminous coals taken from Jindi coal mine of Shanxi Province in China. The influence of moisture was ignored because the studied coal had low moisture content (mass concentration: 1.87%) and both coal and ambient environment were assumed to be saturated with moisture (or ambient environment was assumed to be dry). The effects of five variables (i.e. wind velocity, oxygen concentration, height, porosity, and side slope) on the spontaneous ignition in coarse coal piles were examined. Simultaneously, a theoretical prediction model was formulated in light of variable analyses and a great number of simulations. Compared to self-ignition characteristics of fine-particle coal piles, several self-ignition characteristics of coarse coal piles were identified by numerical investigation. Wind-driven forced convection plays a predominant role in self-heating of coarse coal piles. As wind velocity increases, the self-ignition location in the pile migrates from the lower part which is close to the surface of the windward side to the upper part near to the surface of the leeward side. Wind velocity increase exerts the positive or the negative effect on self-heating, which depends on a critical wind velocity value to sustain balances of both the heat and the availability of oxygen in the coarse coal pile. The behaviour of self-ignition is remarkably sensitive to both oxygen concentration and height, and a coarse coal stockpile will not ignite spontaneously as long as one of two critical variable values is satisfied: oxygen concentration of 5% or height of 3 m. The theoretical prediction model suggests when and where countermeasures should be made to prevent the self-ignition in the coal stockpile with engineering accuracy.

Economics, business, marketing, policy

13/03151 Assessment of clean-coal strategies: the questionable merits of carbon capture-readiness

Rohlfs, W. and Madlener, R. *Energy*, 2013, 52, 27–36.

This paper investigates the value of capture-readiness by modelling the cost effectiveness of various alternative technological options and focusing on different clean-coal technology pathways. The modelling framework developed is based on stochastic net present value calculations. It allows for consideration of path-dependent and technology-specific risk combinations inherent in the input and output commodities that are relevant for operating the plant. It was found that capture-readiness competes with alternative options of power plant replacements and that capture-readiness is not necessarily preferable from an economic perspective.

13/03152 China's coke industry: recent policies, technology shift, and implication for energy and the environment

Huo, H. *et al. Energy Policy*, 2012, 51, 397–404.

China is the largest coke producer in the world, accounting for over 60% of the world coke production, which makes the coke industry in China a significant coal consumer and air pollutant emitter. Recently, China has taken a series of measures to improve energy efficiency and reduce emissions from the coke industry, including eliminating old and low energy-efficiency coking technologies, promoting advanced technologies, and strengthening energy and environmental requirements on coking processes. As a consequence, China's coke industry is experiencing an unprecedented technology shift, which was characterized by the elimination of old, inefficient, and polluting indigenous ovens and small machinery ones within 10 years. This study examines the policies and the prompt technology shift in China's coke industry, as well as the associated energy and environmental effects, and discusses the implications with respect to the development of the coke industry in China towards a more efficient and clean future. As China sets stricter requirements on energy efficiency and the ambient environment, a more significant change focusing on technologies of energy saving and emission reduction is urgently needed at present. Those mature technologies, including coke dry quenching, coke oven gas recycle, fine particle removal, etc., should be enforced in the near future.

13/03153 Japanese investment in Australian coal assets through the demise of concessional financing

West, J. *Energy Policy*, 2013, 52, 513–521.

The Australian coal industry has been described as being a perpetual case of 'profitless prosperity'. This implies that foreign companies invest in low-margin mining activities with motives other than profit. It is argued that foreign investors and Japanese trading companies in particular used government investment concessions and subsidies to help create oversupply in the seaborne coal market. The aim of this strategy is to depress contract prices at the cost of achieving reasonable profitability levels, which have historically been well below that of other investors in the Australian mining sector. This study shows that the quasi-integration via concessional funding arrangements is not a credible strategy employed by Japanese trading companies or the Japanese Government. The analysis rejects the hypothesis that via foreign direct investment, Japanese companies are securing coal at below average prices. Furthermore no clear evidence was found of Japanese trading companies using their information advantage as equity investors to secure coal at favourable prices during contract negotiations. Finally the investment behaviour of new entrants in the Australian coal production sector was examined to highlight the differences in investment strategy between Japanese companies and other foreign investors regarding the security of supply.

13/03154 Shale gas vs. coal: policy implications from environmental impact comparisons of shale gas, conventional gas, and coal on air, water, and land in the United States

Jenner, S. and Lamadrid, A. J. *Energy Policy*, 2013, 53, 442–453.

The aim of this paper is to examine the major environmental impacts of shale gas, conventional gas and coal on air, water, and land in the USA. These factors decisively affect the quality of life (public health and safety) as well as local and global environmental protection. Comparing various lifecycle assessments, this paper will suggest that a shift from coal to shale gas would benefit public health, the safety of workers, local environmental protection, water consumption, and the land surface. Most likely, shale gas also comes with a smaller greenhouse gas footprint than coal. However, shale gas extraction can affect water safety. This paper also discusses related aspects that exemplify how shale gas can be more beneficial in the short and long term. First, there are technical solutions readily available to fix the most crucial problems of shale gas extraction, such as methane leakages and other geo-hazards. Second, shale gas is best equipped to smooth the transition to an age of renewable energy. Finally, this paper will recommend hybrid policy regulations.

13/03155 Surface coal mine land reclamation using a dry flue gas desulfurization product: long-term biological response

Chen, L. *et al. Fuel*, 2013, 105, 258–265.

Abandoned surface coal mined lands are a worldwide environmental concern due to their low productivity and potential negative impact on water and soil quality. A field study was conducted to investigate the use of a dry flue gas desulfurization (FGD) product, i.e. a fluidized bed combustion (FBC) product, for reclamation of an abandoned surface coal mined land in Ohio, USA. The FGD product was applied to the mine site at a rate of 280 $\mathrm{Mg\,ha^{-1}}$ alone or with 112 $\mathrm{Mg\,ha^{-1}}$ yard waste compost, and these treatments were compared to a conventional reclamation treatment that included 20 cm of resoil material plus 45 $\mathrm{Mg\,ha^{-1}}$ of agricultural limestone. A grass-legume sward was planted, and plant biomass yields and elements in plant tissues were determined as long as 16 years after treatments. Bacterial populations and diversity and microbial biomass C in the reclaimed surface coal mined land were analysed in the 16th year after treatments. Compared with the conventional soil treatment, plant biomass on plots treated with FGD product was lower in the first and third years, not different in the 14th year, and higher in the 16th year after application. Magnesium, S, Mo and B concentrations in plant tissues were increased by the treatments with FGD product in the first three years but not in the 14th year after application, and the heavy metals measured were not significantly increased. Bacterial populations and diversity and microbial biomass C in the reclaimed coal mine plots were significantly increased compared to adjacent untreated area and were generally similar among reclamation treatments. These results suggest that use of FGD product, used alone or in combination with compost, for reclamation of acidic surface coal mined lands can provide effective, long-term remediation.

13/03156 The safety regulation of small-scale coal mines in China: analysing the interests and influences of stakeholders

Song, X. and Mu, X. *Energy Policy*, 2013, 52, 472–481.

Small-scale coal mines (SCMs) have played an important role in China's energy supply. At the same time, they also suffer from many social, economic, environmental, and safety problems. The Chinese government has made considerable efforts to strengthen the safety regulation of the coal mining industry. Yet, few of these efforts have proven to be very effective. This paper analyses the interests and influences of key stakeholders in the safety regulation of SCMs, which includes the safety regulator, the local government, the mine owner, and mineworkers. It is argued that the effective regulation of coal mine safety must both engage and empower mineworkers.

Derived solid fuels

13/03157 Effect of coke contraction on mean coke size

Nomura, S. and Arima, T. *Fuel*, 2013, 105, 176–183.

In order to develop a coal blending technology to control the size of blast furnace coke, the authors investigated the relationship between coke size and the contraction behaviour of semi-coke after resolidification which is one of the factors determining coke size. Coke contraction after resolidification was measured successfully by heating the coal sample from room temperature to 1000 °C using a high-temperature dilatometer. The contraction coefficient of coke showed a first maximum near the resolidification temperature (contraction beginning temperature), a first minimum at around 550 °C and a second maximum at around 700 °C. The measurement of contraction characteristics of 15 coals confirmed that the first maximum of coke contraction coefficient varied according to the type of bituminous coals and was independent of coal VM (volatile matter) and Ro (vitrinite reflectance). On the other hand, the contraction coefficient of coke after the first minimum (at around 550 °C) was nearly independent of the type of bituminous coals. The coke contraction ratio between the resolidification temperature and 1000 °C increased with increasing the first maximum of coke contraction coefficient. It was confirmed both in laboratory scale and in commercial scale that mean coke size is strongly associated with coke contraction ratio after resolidification and that mean coke size increases with decreasing coke contraction ratio. In view of the information and data presented in this paper, a practical application of the technology to control coke size by coal blending based on the coke contraction percentage of each coal is expected.

13/03158 Experimental study of natural gas hydrates and a novel use of neural network to predict hydrate formation conditions

Ghavipour, M. *et al. Chemical Engineering Research and Design*, 2013, 91, (2), 264–273.

A novel high-pressure apparatus with various abilities in hydrate investigation fields has been designed, constructed and fully described in the present paper. In order to achieve an appropriate understanding of the gas hydrate behaviour in formation and destabilization, series of laboratory experiments with six different gas mixtures were done and more than 130 hydrate equilibrium points in the pressure range of about 450–3000 psia were recorded. Different methods of hydrate formation prediction were discussed and finally the new promising neural networks method was used. Because of the previous works defects in accurate hydrate formation prediction via neural networks, a new use of neural networks was introduced. Testing and validation of the new neural networks method indicates that it is a reliable technique for the accurate prediction of hydrate formation conditions for generalized gas systems and can be used in future automatic inhibitor dosing devices.

13/03159 Oxy-fuel combustion of millimeter-sized coal char: particle temperatures and NO formation

Brix, J. *et al. Fuel*, 2013, 106, 72–78.

In this work, differences in particle temperature and NO yield during char oxidation in O_2/N_2 and O_2/CO_2 atmospheres, respectively, have been examined. A laboratory scale fixed bed reactor, operated isothermally at 1073 K, was used for combustion of millimetre-sized lignite and bituminous coal char particles in 5–80 vol.% O_2. Experiments were carried out with both single particles of different sizes (1.3–543 mg) and multiple particles (30–50 mg). Particle temperatures and structural changes were recorded by a charged coupled device camera during the experiments. The particle surface temperatures increased with mass loading, by as much as 700 K above the furnace set point. The formation of NO from lignite char was not influenced by the change from N_2 to CO_2 whereas the NO yield from bituminous coal char was considerably lower in O_2/CO_2 compared O_2/N_2. For both chars the conversion to NO decreased as the O_2 concentration or the particle size increased. However, for the bituminous coal char, a peak in NO yield was observed at an intermediate particle size of 0.1–0.2 g. The differences in the effect of gas atmosphere, O_2 concentration, and particle mass on the NO yield from oxidation of bituminous coal char and lignite char, respectively, cannot be fully explained. Char/NO interactions appear to be quite complex, and mineral catalysis and release to the gas-phase of volatile N-species such as HCN, either from secondary pyrolysis or as a product of the char–N + O_2 reaction, may play a role.

13/03160 Platinum nanoflowers decorated three-dimensional graphene–carbon nanotubes hybrid with enhanced electrocatalytic activity

Rajesh, *et al. Journal of Power Sources*, 2013, 223, 23–29.

A three-dimensional carbon electrode, in the form of vertically grown multiwalled carbon nanotubes (MWNTs) on a single layer graphene floor (G-MWNTs) is synthesized by one-step chemical vapour deposition (CVD) method, as supporting material for platinum (Pt) electrocatalyst. Nanostructured Pt catalyst is electrodeposited onto this 3D-carbon electrode and their structural and electrochemical properties are investigated by transmission electron microscopy (TEM), scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), cyclic voltammetry (CV) and electrochemical impedance spectroscopy. The electrocatalytic performance of the modified electrode (Pt/G-MWNTs) towards methanol oxidation is also investigated by CV. Experimental results demonstrate an enhanced efficiency of the G-MWNTs hybrid film, as Pt catalyst support, for methanol oxidation in comparison to pristine single layer graphene electrode with regard to electroactive surface area, forward anodic peak current density, onset oxidation potential, diffusion efficiency and the ratio of forward to backward anodic peak current density (I_f/I_b). This enhanced electrochemical and catalytic performance towards methanol oxidation is attributed to the high surface area of three-dimensional G-MWNTs hybrid film due to synergistic combination of both structural and electrical properties of 2D-graphene and 1D-MWNTs, allowing higher dispersion of Pt.

13/03161 Pyrolysis of pine and gasification of pine chars – influence of organically bound metals

Aho, A. *et al. Bioresource Technology*, 2013, 128, 22–29.

Pyrolysis of pine and gasification of pine chars was studied in this work, focusing on the influence of organically bound metals. Selective leaching of the major ash-forming elements in pine wood was performed with different acids, namely, nitric, sulfuric, hydrochloric and oxalic acids. No other major changes in the chemical composition of the biomass were observed except the removal of the metals. The effect of organically bound sodium, potassium, magnesium and calcium was studied in both pyrolysis and gasification. Removal of the metals had a positive effect on the pyrolysis, resulting in higher bio-oil, lower char and gas yields.

13/03162 Spectroscopic evaluation of individually dispersed single-walled carbon nanotubes

Khalid Najeeb, C. and Kim, D. *Carbon*, 2013, 52, 219–224.

The authors prepared the individually dispersed solutions of various single-walled carbon nanotubes (SWCNTs) synthesized by electric arc discharge, catalytic chemical vapour deposition, and high-pressure carbon monoxide process using the biocompatible chitosan derivative, chitosan hydroxyphenylacetamide, and evaluated their dispersion efficiencies. The authors propose a new spectroscopic parameter for quantitative evaluation of the individually dispersed SWCNTs and present the optimum SWCNT-to-dispersant ratio for high-quality dispersion of each SWCNT type based on the proposed parameter.

13/03163 Synthesis of graphene nanosheets from petroleum asphalt by pulsed arc discharge in water

Li, Y. *et al. Chemical Engineering Journal*, 2013, 215–216, 45–49.

The synthesis of graphene nanosheets has been achieved by pulsed arc discharge in water with petroleum asphalt as a carbon source. The synthesized graphene nanosheets were examined by Raman spectroscopy, transmission electron microscopy, X-ray photoelectron spectroscopy, infrared spectroscopy and atomic force microscopy. The results indicate that most of as-synthesized graphene nanosheets have two to five layers, and small amounts of them have sheets in the range of five to 10 layers. The optical emission spectroscopy was used to monitor the arc discharge process, which indicates that the released hydrogen from asphalt may play a key role in the formation of graphene.

02 LIQUID FUELS

Sources, properties, recovery

13/03164 A novel heat flux burner system to determine the laminar flame velocity of liquid fuels

Knorsch, T. *et al. Fuel Processing Technology*, 2013, 107, 119–125.

This article addresses burner design and flame measurement based on the heat flux method which is among the most precise ways of determining the laminar burning velocity of premixed flames. Chemical data are available for gaseous fuel flames using a variety of burner setups. However, the data for the laminar burning velocities of liquid fossil fuels and alternative biofuel blends, are still either incomplete, inaccurate or vary strongly for different setups, burner types and boundary conditions. A modified heat flux approach is found to increase the accuracy of the results of laminar burning velocities. For this purpose, a heat flux gas burner was combined with a novel liquid-fuel injection evaporating system called ‘HeatFluxER’ to achieve precise data for various biofuels and blends. Nevertheless, the purpose of this work is to obtain a robust inexpensive system for reproducible measurements. The gained measurement data of ethanol and isooctane depending on the initial gas temperature are in good agreement with recently presented studies of other groups and setups.

13/03165 Application of GC–MS chromatography for the analysis of the oil fractions extracted by supercritical CO_2 at high pressure

Rudyk, S. *et al. Fuel*, 2013, 106, 139–146.

GC–MS chromatographic analysis has been applied for the investigation of the fractions of oil extracted by supercritical carbon dioxide at a temperature of 60 °C and at pressure values ranging from 22 to 56 MPa. The observations revealed, that the whole extraction process is clearly reflected in the chromatograms, demonstrating how the heavier hydrocarbon fractions were gradually involved in the extraction process. The shape of the chromatograms alters with increasing pressure from triangle to trapezoid, approaching the shape of the chromatogram of the crude oil. The observation of the fingerprints of chromatograms allows them to be used for the qualitative evaluation of extraction progression. It can also be noticed, that the area under the spectrum of the chromatograms of oil samples extracted at various pressures is increasing with an increase in pressure. The oil recoveries, evaluated as the ratio of the area under the spectrum or the baseline of the chromatogram of the sample extracted at the specific pressure value to the area under the spectrum or the baseline of the chromatogram of the crude oil, showed a close correlation with the oil recoveries obtained from the experiment. This allows the use of the chromatographic method for the quantitative evaluation of oil recovery.

13/03166 Effects of exhaust gas recirculation on low temperature combustion using wide distillation range diesel

Feng, H. *et al. Energy*, 2013, 51, 291–296.

The experiments were performed using a modified six-cylinder turbocharged direct injection diesel engine with diesel of different distillation ranges to investigate the effects of exhaust gas recirculation (EGR) on engine performance and emission characteristics of low-temperature combustion engine. The results showed that for the same fuel, with the increase of the EGR rate, the cylinder pressure remained almost unchanged. Increasing the EGR rate slowed the combustion, the peak value of heat release rate increased and the indicated thermal efficiency decreased. The peak value of heat release rate increased with the decline of the initial boiling point at the same EGR rate. The ignition delay of combustion increased with the decrease of initial boiling point. When EGR rate was low, the level of HC and CO emission was low, while the HC and CO emission increased rapidly with the increase of EGR. The NO_x emission was reduced with the increase of the EGR rate. The study also showed that the wide distillation range diesel can reduce emission over diesel in low temperature combustion. Wide distillation range fuel had potential to reduce soot emission at different EGR for low temperature combustion engine.

13/03167 Evaluation of the hybrid process of electrical resistive heating and solvent injection through numerical simulations

Zhu, Z. *et al. Fuel*, 2013, 105, 119–127.

Electrical resistive heating (ERH) has been proposed as a thermal recovery method for heavy oil reservoirs with low environmental impact. ERH could potentially be an alternative to steam-related processes in the reservoirs which are not suitable for steam injection methods due to low incipient injectivity and formation incompatibility. Meanwhile, vapour extraction (VAPEX) has been tested as an environmentally sustainable oil recovery method in both lab scale and field scale. However, the field test results showed that this process is not efficient and economical due to low mass transfer and low horizontal well efficiency. This paper presents a hybrid process of ERH with VAPEX. The hybrid process could enhance horizontal well efficiency and overall oil production rate, with less environmental impact than other steam-related thermal processes. Numerical simulations were conducted to evaluate this process via a steam, thermal, and advanced processes reservoir simulator. A well pattern similar to that in classical steam-assisted gravity drainage process is used. The electrode is placed along with the producer or injector and solvent is injected from the injector. This process has three features which contribute to the enhanced oil flow: (1) the heat from electrode establishes good communication between the injector and the producer by viscosity reduction; (2) the *in situ* generated heat through ERH along with the horizontal wellbore is insusceptible to reservoir heterogeneity. Thereby the horizontal well conformity can be improved; (3) the solvent can reduce the viscosity of the heavy oil in unheated zone where the ERH cannot reach; it can also assist viscosity reduction of heavy oil in the heated zone. The factors affecting this hybrid process, such as electrode placement, voltage, well distance and heterogeneity effect, lateral pattern and water saturation, were also discussed in this paper. The simulation results showed that this hybrid process can improve the oil rate 2–5 times over VAPEX.

13/03168 High temperature ignition delay times of C5 primary alcohols

Tang, C. *et al. Combustion and Flame*, 2013, 160, (3), 520–529.

Ignition delay times of the three C5 primary alcohol isomers (*n*-pentanol, *iso*-pentanol and 2-methyl-1-butanol) were measured behind reflected shock waves. Experiments were conducted in the temperature range of 1100–1500 K, pressures of 1.0 and 2.6 atm, equivalence ratios of 0.25, 0.5 and 1.0, and O_2 concentration in the fuel/O_2/Ar mixtures varying from 3.75% to 15%. Measurements show that the ignition delay time and the global activation energy of the three isomers both decrease in the order of *iso*-pentanol, 2-methyl-1-butanol, and *n*-pentanol. Chemical kinetic mechanisms for *n*-pentanol (Mech NP) and *iso*-pentanol (Mech IP), recently developed elsewhere, were used to model the respective ignition delay times. Results show that Mech NP yields close agreement at the equivalence ratio of 0.25, but the agreement is moderated with increasing equivalence ratio. Mech IP yields fairly close agreements at relatively higher temperatures but over-predicts the measurements by 50% at relatively lower temperatures for the three equivalence ratios studied. A new 2-methyl-1-butanol high temperature mechanism was proposed and validated against the ignition delay data. Sensitivity analysis for both *n*-pentanol and *iso*-pentanol showed the dominance of small radical reactions. Reaction pathway analysis aided further scrutiny of the fuel-specific reactions in Mech NP, leading to refinement of the kinetic model, and improved agreement between the predicted and measured ignition delay times as well as the jet-stirred reactor results.

13/03169 Study of cavitation phenomenon using different fuels in a transparent nozzle by hydraulic characterization and visualization

Payri, R. *et al. Experimental Thermal and Fluid Science*, 2013, 44, 235–244.

In this paper the behaviour of the internal flow under cavitating conditions and the influence of using different fuels is studied. For this purpose, a transparent nozzle (quartz plate) with a cylindrical orifice and four different fuels are used. The nozzle is installed in a pressurized rig with fuel in order to measure the mass flow and observe the flow inside the orifice using a special visualization technique with all fuels. Since the refractive index of the vapour bubbles of the fuel is different to the refractive index of the fuel in liquid state, the cavitation inside the nozzle can be appreciated. Pressure conditions at which the first bubbles inside the orifice appear are compared with the pressure conditions for mass flow collapse, showing that the beginning of the cavitation occurs before the mass flow collapse and that it depends both on the upstream and downstream pressure conditions and on the fluid viscosity used. Additionally it is observed that the mass flow collapse takes place once the cavitation is fully developed through the whole orifice and the presence of bubbles in the spray before the mass flow collapse indicating that the cavitation appears before the mentioned collapse.

13/03170 The palaeobiology and geochemistry of Precambrian hydrocarbon source rocks

Craig, J. *et al. Marine and Petroleum Geology*, 2013, 40, 1–47.

Organic carbon productivity and formation of hydrocarbon source rocks during the Early Precambrian was almost exclusively the product of the growth of microbial mats. Indirect evidence of microbial mats can be traced back to at least 2.6–2.7 Ga (Neoarchaean), with the earliest evidence of mat development in siliciclastic sediments coming from the 2.9 Ga (Mesoarchaean), predominantly marine sedimentary rocks of the Mozaan Group in South Africa. The earliest direct evidence for terrestrial microbial mats in siliciclastic sediments comes from the 2.75 Ga (Palaeoproterozoic) fluviolacustrine sediments of the Hardey Formation of the Pilbara craton in Western Australia. Well-preserved Proterozoic hydrocarbons provide valuable information about the early evolution of the biosphere. Eukaryotic steranes (biomarker for eukaryotic cells and, therefore, evolved forms of life) are present in the geological record from about 2.7 Ga, but they are not abundant or diverse within Archaean communities, which tend to be dominated by Archaea isoprenoids. Some hydrocarbons have been generated and migrated from Archaean organic-rich shales, but they were probably not of sufficient volume to be of commercial interest. The world's oldest significant hydrocarbon source rocks are Palaeoproterozoic in age and include the shungite deposits (2.0 Ga) in the Lake Onega region of Arctic Russia. There is strong evidence of a global biospheric oxygenation event at *ca.* 1300–1250 Ma (Mesoproterozoic) in conjunction with a first-order positive shift in the marine carbon isotope record. This is supported by the appearance of the oldest bedded marine gypsum deposits and of the earliest, unambiguously multicellular eukaryotes at this time. This oxygenation event probably played a significant role in supporting the more diverse eukaryotic communities preserved in the Neoproterozoic molecular record and provided the volume of organic material required to generate commercial volumes of hydrocarbons. Hydrocarbon source rocks of late Mesoproterozoic and Early Neoproterozoic age are widespread and include highly organic-rich shales deposited in restricted basinal settings adjacent to stromatolitic carbonate banks. By *ca.* 850 Ma, the Neoproterozoic molecular record is dominated by hopanes from cyanobacteria with a significant abundance and diversity of eukaryotic steranes, including those of multicellular eukaryotes (red and green algae), as well as molecular evidence for heterotrophic protists. The most widespread hydrocarbon source rocks of mid to late Neoproterozoic age are commonly transgressive organic-rich black shales associated with inter-glacial and post-glacial phases of the Neoproterozoic global scale glaciations. The relative dominance of microbial mats in the contribution of organic matter as a source for hydrocarbon generation probably decreased significantly during the late Neoproterozoic and earliest Cambrian, perhaps as a result of the rapid growth of grazing metazoan communities or possibly as a result of changes in seawater chemistry and/or nutrient supply. Precambrian and 'Infracambrian' petroleum systems are relatively abundant and widespread. The oldest live oil recovered to date is sourced from Mesoproterozoic rocks within the Velkerri Formation (Roper Group) of the McArthur Basin of northern Australia, dated at 1361 ± 21 and 1417 ± 29 Ma (Re–Os dates) with at least the initial phase of oil generation and migration having taken place before 1280 Ma. However, the geologically oldest commercial production is currently from the somewhat younger mid to Late Neoproterozoic (Cryogenian–Ediacaran) petroleum systems of the Lena-Tunguska province in East Siberia and in southern China, from the latest Neoproterozoic to Early Cambrian Huqf Supergroup in Oman and, potentially in the near future, from the age-equivalent Mawar Supergroup in western India.

13/03171 Thermal maturity of northern Appalachian Basin Devonian shales: insights from sterane and terpane biomarkers

Hackley, P. C. *et al. Fuel*, 2013, 106, 455–462.

To better estimate thermal maturity of Devonian shales in the northern Appalachian Basin, 11 samples of Marcellus and Huron Shale were characterized via multiple analytical techniques. Vitrinite reflectance, Rock–Eval pyrolysis, gas chromatography (GC) of whole rock extracts, and GC–mass spectrometry (GCMS) of extract saturate fractions were evaluated on three transects that lie across previously documented regional thermal maturity isolines. Results from vitrinite reflectance suggest that most samples are immature with respect to hydrocarbon generation. However, bulk geochemical data and sterane and terpane biomarker ratios from GCMS suggest that almost all samples are in the oil window. This observation is consistent with the presence of thermogenic gas in the study area and higher vitrinite reflectance values recorded from overlying Pennsylvanian coals. These results suggest that vitrinite reflectance is a poor predictor of thermal maturity in early mature areas of Devonian shale, perhaps because reported measurements often include determinations of solid bitumen reflectance. Vitrinite reflectance interpretations in areas of early mature Devonian shale should be supplanted by evaluation of thermal maturity information from biomarker ratios and bulk geochemical data.

Transport, refining, quality, storage

13/03172 An efficient biosurfactant-producing and crude-oil emulsifying bacterium *Bacillus methylotrophicus* USTBa isolated from petroleum reservoir

Chandankere, R. *et al. Biochemical Engineering Journal*, 2013, 74, 46–53.

An efficient biosurfactant-producing bacterium was isolated and cultured from petroleum reservoir in north-east China. Isolate was screened for biosurfactant production using haemolytic assay, cetyl trimethyl ammonium bromide agar plate assay (CTAB) and the qualitative oil-displacement test. Based on partial sequenced 16S rDNA analysis of isolate, USTBa, identified as *Bacillus methylotrophicus* with 100% identity. This bacterium was able to produce a type of biosurfactant with excessive foam-forming properties. The maximum biosurfactant production was obtained when the cells were grown on minimal salt medium containing 2% (v/v) crude-oil as the sole source of carbon at 35 °C and 180 rpm after 192 h. This strain had a high emulsification activity and biosurfactant production of 78% and 1.8 g/L respectively. The cell free broth containing biosurfactant could reduce the surface tension to 28 mN/m. Fourier transform infrared spectrum of extracted biosurfactant indicates the presence of carboxyl, hydroxyl and methoxyl functional groups. Elemental analysis of the biosurfactant by energy dispersive X-ray spectroscopy reveals that the biosurfactant was anionic in nature. The strain USTBa represented as a potent biosurfactant-producer and could be useful in variety of biotechnological and industrial processes, particularly oil industry.

13/03173 Assessing the impact of oil returns on emerging stock markets: a panel data approach for ten central and eastern European countries

Asteriou, D. and Bashmakova, Y. *Energy Economics*, 2013, 38, 204–211.

This paper uses an international multi-factor model in order to investigate the relationship between oil price risk and stock market returns for the emerging capital markets of the central and eastern European countries (CEECs). A panel data approach is being employed for the period covering 22 October 1999 until 23 August 2007. The oil price beta is found to be negative and statistically significant suggesting that the oil price is indeed an important factor in determining stock returns. No statistically significant non-linear dependency is found between market risk and emerging market stock returns or between oil price risk and returns. Observation of conditional models shows positive reaction of emerging stock market returns to upward movements of market returns. The reaction of the stock returns to upward and downward movements of the oil market is also negative but more significant when oil prices are low.

13/03174 Biotreatment of heavy oil wastewater by combined upflow anaerobic sludge blanket and immobilized biological aerated filter in a pilot-scale test

Liu, G.-h. *et al. Biochemical Engineering Journal*, 2013, 72, 48–53.

A field pilot study has been constructed in the Liaohe oilfield, China to treat heavy oil wastewater with large amounts of dissolved recalcitrant organic compounds and low nutrient of nitrogen and phosphorus by an upflow anaerobic sludge blanket (UASB) coupled with immobilized biological aerated filters (I-BAFs). By operating the system for 252 days (including the start-up of 128 days), the chemical oxygen demand (COD), ammonia nitrogen (NH_3-N) and suspended solid (SS) in the wastewater were removed by 74%, 94% and 98%, respectively. GC–MS analysis indicated that most of alkanes were degraded by the UASB process, while the I-BAF played important roles both in degrading organic compounds and in removing the NH_3-N and SS. The bacterial community structural analysis based on the PCR-DGGE technology reveals that the predominant bacteria in the UASB reactor belong to the *Bacillales* and *Rhodobacterales*, and that in the I-BAF was identified as uncultured soil bacterium. The results suggest that the combined biotreatment system has immense potential in large-scale treatment of heavy oil wastewater.

13/03175 Computational procedure for determination of minimum miscibility pressure of reservoir oil

Fazlali, A. *et al. Fuel*, 2013, 106, 707–711.

A methodology has been developed for computing minimum miscibility pressure (MMP) for the displacement of oil by multi-component gas injection. (It is focused on multiple contact miscibility mechanism (forward/backward).) The algorithm is presented for the calculation of the minimum miscibility pressure using an equation of state. The Peng–Robinson equation of state along with random mixing rules is used to determine phase behaviour of oil and gas. The key assumption of the method is that the MMP is completely independent of the porous media. This algorithm handles vaporizing (forward multiple contact) miscibility mechanisms. The MMP calculations include pressure/temperature flash calculations and oil properties characterization method of Riazi–Daubert. The proposed algorithm is fast and easy to compute.

13/03176 Damage detection in offshore platform structures from limited modal data

Wang, S. *Applied Ocean Research*, 2013, 41, 48–56.

Development of efficient global damage detection techniques for offshore structures is of great importance. The present paper applies the iterative modal strain energy (IMSE) method to locate and quantify the damage for three dimensional frame structures, when limited, spatially incomplete modal data are available. One theoretical development is a new procedure to directly incorporate the spatially-incomplete mode shapes in the algorithm, where slave degrees of freedom iterative updating procedure (SDUP) is developed for evaluating the damage indicator and damage severity. The merits of this new method are that both the modal frequencies and spatially incomplete mode shapes can be used. Also, the modal frequencies do not need to pair the mode shapes one by one. To demonstrate the feasibility and effectiveness of the developed algorithm, numerical studies are conducted for a three-dimensional (3D) offshore platform based on data generated from finite element models. Numerical results demonstrate that the present method is effective for the damage assessment of a 3D frame structures when limited, spatially incomplete modal data are available. After considering more practical factors, it is expected to be more applicable in structural damage assessment.

13/03177 Fischer–Tropsch product as a co-feed for refinery hydrocracking unit

Šimáček, P. *et al. Fuel*, 2013, 105, 432–439.

A flow bench scale fix-bed reactor was used for hydrocracking experiments, which were carried out over a commercial Ni–W/alumina catalyst under hydrogen pressure of 18 MPa. Two feeds were separately processed at temperature levels of 390, 410 and 430 °C: vacuum distillate containing 10 wt% of Fischer–Tropsch (FT) product prepared in separate experiments and neat vacuum distillate used as a reference material. The hydrocracking products were fractionated by distillation into naphtha, diesel oil and residue. All samples were then analysed using several analytical methods in order to compare properties of the products obtained from different feeds. All products obtained from the feed containing FT product had lower or comparable density and sulfur content to products obtained from neat vacuum distillate. Differences in hydrocarbon group-type composition were observed in both naphtha and diesel fractions. The impact of modification of vacuum distillate by FT product on the properties of its hydrocracking products is discussed in detail.

13/03178 Measurement and modeling of the phase behavior of solvent diluted bitumens

Agrawal, P. *et al. Fluid Phase Equilibria*, 2012, 334, 51–64.

The design of solvent-based and solvent assisted heavy oil recovery processes requires accurate predictions of phase behaviour as straightforward as saturation pressures and as potentially complex as vapour–liquid–liquid equilibria and asphaltene precipitation. It is a challenge to predict this variety of phase behaviour from a single fluid model. In this study, saturation pressures of dead and live Peace River bitumen were measured in a Jefri PVT cell at different concentrations of a multi-component solvent at temperatures from 20 to 180 °C. Saturation pressures and the onset of asphaltene precipitation were also measured for the bitumen diluted with *n*-pentane. The onset of precipitation was determined by titrating the bitumen with pentane and periodically circulating the mixture past a high pressure microscope. Literature data including saturation pressures and liquid–liquid phase boundaries for pseudo-binaries of bitumen and carbon dioxide, methane, ethane, and propane were also evaluated. The data were modelled with the advanced Peng–Robinson equation-of-state (APR EoS). The maltene fraction of the bitumen was characterized into pseudo-components based on extrapolated distillation data. The asphaltenes were characterized based on a Gamma distribution of the molecular weights of self-associated asphaltenes. The APR EoS was tuned to fit the saturation pressure and asphaltene onset data of the pseudo-binaries by adjusting the binary interaction parameter between the solvent and the bitumen pseudo-components. A temperature dependent binary interaction parameter correlation was developed for the interaction parameters. The model fit the saturation pressures and onset of asphaltene precipitation over a wide range of temperatures. The model predicted liquid–liquid boundaries as well as the saturation pressures of live oil and live oil diluted with condensate solvent, generally within experimental error. The model also predicted the asphaltene onset in propane diluted bitumen.

13/03179 Oil price asymmetric effects: answering the puzzle in international stock markets

Ramos, S. B. and Veiga, H. *Energy Economics*, 2013, 38, 136–145.

Although studies have found an asymmetric pattern in the response of aggregate output to oil price changes, parallel studies in stock markets have not been conclusive about their existence. This paper finds evidence that effects for oil-importing and oil-exporting countries run in opposite directions. Oil price hikes have a negative effect on the stock markets of oil-importing countries, while the impact is positive for the stock markets of oil-exporting countries. Statistical tests support the presence of asymmetric effects only in oil-importing countries. Oil price volatility has a negative impact in stock markets of oil-importing countries and positive in oil-exporting countries. Moreover, oil volatility seems to be affected asymmetrically by oil price changes. Oil price drops increase oil volatility more than oil price hikes do. Overall, the evidence seems to support that falls in oil prices do not impact stock markets because their positive effects are offset by negative effects of oil price volatility, cancelling out effects for oil-importing countries.

13/03180 Online estimation of wax deposition thickness in single-phase sub-sea pipelines based on acoustic chemometrics: a feasibility study

Halstensen, M. *et al. Fuel*, 2013, 105, 718–727.

Wax deposition in sub-sea oil producing pipelines is a concern to the oil producing companies. The deposition of wax in pipelines can cause serious economic implications if not monitored and controlled. Several researchers have developed models and investigated the deposition of wax in crude oil pipelines. As of today, there is no ‘off the shelf’ instrument available for reliable online estimation of the wax deposition thickness in sub-sea pipelines. Acoustic chemometrics was applied to investigate the potential for online estimation of wax deposition thickness in sub-sea pipelines. This feasibility study was carried out as a so-called ‘piggy back’ on experiments performed at Statoil research centre in Porsgrunn, Norway with real crude oil or waxy gas condensate. The first investigations focused on the repeatability of the acoustic chemometric technique followed by online prediction of the wax deposition thickness in a single-phase oil flow pipeline. A partial least squares regression model was calibrated and validated with a totally independent data set. The calibrated model had a root mean squared error of prediction of 0.28 mm with a final wax deposition thickness of 3.36 mm, a slope of 0.91 and R^2 of 0.83 which were satisfactory results. The effect of varying oil flow rates on the wax deposition thickness was also investigated. The preliminary results showed the need for further investigations based on a robust experimental design and sample pre-processing. The general conclusion that can be drawn from this feasibility study was that the potential of adapting the acoustic chemometric technique for online estimation of the wax deposition thickness exist and must be further investigated.

13/03181 Pipe flow of water-in-crude oil emulsions: effective viscosity, inversion point and droplet size distribution

Plasencia, J. *et al. Journal of Petroleum Science and Engineering*, 2013, 101, 35–43.

The present work is a comparative study of the pipe flow of water-in-crude oil emulsions. The pipe flow of emulsions based on six different crude oils (viscosities from 4.8 to 23.5 mPa s) and salt water (3.5% NaCl w/v, pH = 7.3) were investigated experimentally using a small-scale flow loop. The formation of the emulsions was induced by the flow shear itself by circulating the oil–water mixture in a closed loop system (pipe inside diameter 2.2 cm). The effective viscosity of the emulsions as a function of the water fraction was calculated from pressure drop measurements. The phase inversion points and the *in situ* droplet size distributions were also measured and a SARA analysis was made on all crudes. The point of inversion was observed to be fluid dependent. Not all fluids could be circulated through the inversion point due to prohibitive large pressure drops. All fluids turned to laminar flow conditions as the water cut increases towards the inversion point. The emulsions viscosities of six crudes show a similar increase with water cut up to about 30% where larger differences are observed. The effective viscosities were not sensitive to the mixture velocities (0.4–1.0 m/s for constant water cut). Higher shear rates resulting from increasing the mixture velocity lead to the formation of smaller droplets. As the amount of dispersed water increases and gets closer to the inversion point larger droplets show up. The contribution in volume of these coarse droplets was also observed to be important. The experiments with the six crudes illustrate the complexity of oil–water flows and the challenges in understanding the coupling of surface chemistry and fluid flow.

13/03182 Pursuing the pre-combustion CCS route in oil refineries – the impact on fired heaters

Weydahl, T. *et al. Applied Energy*, 2013, 102, 833–839.

The work presented in this paper investigates the effect of replacing refinery fuel gas in the radiant section burners of a fired heater with hydrogen. The aim is to approach pre-combustion carbon capture and storage (CCS) to refinery fired heaters by identifying the impact on heat-, flow- and radiation distribution in the lower radiant section of the fired heater when simply switching refinery gas with hydrogen at equivalent power using the same burner geometrics. Additionally the formation of NO_x is considered. The investigations are performed using a conventional Reynolds average Navier Stokes (RANS), computational fluid dynamics approach using detailed reaction kinetics consisting of 325 elementary reactions and 53 species. Simplified and generalized furnace and burner geometries are used in the present work. The results show that approximately the same average wall heat flux density is achieved when the refinery fuel is replaced by hydrogen. However, the distribution of heat on the inner surfaces changes. The hydrogen case has, as expected, a higher flame temperature than the base case, nevertheless, the nitric oxide (NO_x) emissions are comparable to base case emissions. Several indications point in the direction of a significant contribution to the base case emissions from the less temperature dependent prompt-NO mechanism, which obviously is not contributing to the hydrogen case emissions.

13/03183 Synthesis of hydrothermally stable MCM-41 by the seed crystallization and its application as a catalyst support for hydrodesulfurization

Hussain, M. *et al. Fuel*, 2013, 106, 787–792.

MCM-41 is one of the weak hydrothermally stable members in M41s mesoporous silica family. Therefore, in the present work, an attention has been focused to improve its hydrothermal stability as well as to achieve more acidic sites on its surface structure, in order to make it a good candidate as a support for hydrodesulfurization (HDS) catalysts. Hydrothermally stable MCM-41 (MCM-41(HS)) has been successfully prepared by the seed crystallization method. The synthesized material was analysed by the powder X-ray diffraction, nitrogen adsorption–desorption, ammonia-temperature programmed desorption (NH_3-TPD), chemisorption of carbon monoxide (CO chemisorption), elemental analysis and solid NMR techniques. The characterization results showed that the hydrothermal stability of MCM-41(HS) was significantly improved due to presence of highly cross-linked framework walls, while the mesopore system remained highly ordered. The synthesized MCM-41(HS) has been initially used here as a support to prepare Mo/MCM-41(HS) catalyst for HDS application. The increased zeolitic phase in the wall of mesostructure is believed to increase the HDS activity of MCM-41(HS) supported Mo catalyst in contrast with conventional Al-MCM-41 supported Mo catalyst.

13/03184 Tribological behavior of diesel fuels and the effect of anti-wear additives

Agarwal, S. *et al. Fuel*, 2013, 106, 21–29.

Petrodiesel fuels are complex mixtures whose composition differ from refinery to refinery and according to the type of crude oil processed. They are prepared by blending two types of streams, namely straight run distillate and distillates from upgrading of residues. In order to make diesel fuels to work over a wide variety of working conditions, its properties are fixed to a standard value, which may differ in different countries according to their climate conditions. Also, to reduce pollution, some rules and regulations have been framed so as to limit the amount of harmful components as sulfur, nitrogen in the fuel. Until 1990s, sulfur was accepted up to a maximum value of 500 ppm. But keeping the green environment in view, the regulations have been made more stringent and presently sulfur should not be present beyond 50 ppm or even less in some countries. So, it is required to be removed through different processes. But during those processes many components responsible for lubricity also get removed, leading to the breakdown of fuel distribution pump, engine failure, etc. So, the lubricity is required to be regained with the help of anti-wear additives. The paper reflects light on different types of bio as well as chemical anti-wear additives as lubricity enhancement in ULSD fuels, is still a challenging task for researchers.

Economics, business, marketing, policy

13/03185 A process-based model for estimating the well-to-tank cost of gasoline and diesel in China

Li, W. *et al. Applied Energy*, 2013, 102, 718–725.

This study presents a process-based model to estimate the well-to-tank (WTT) costs of vehicle fuels (gasoline and diesel). The model breaks down the WTT process into four stages, i.e. crude oil sourcing (import and extraction), crude oil transportation, crude oil refining, and vehicle fuel transportation and distribution, which can provide high-resolution data for the WTT cost components. Using this model, an empirical study is developed for China. The results obtained from the study indicate that the price of imported crude oil is the dominant factor affecting the WTT costs of vehicle fuels in China and that the cost of crude oil refining also has a relatively large influence. By comparing the costs with the prices of vehicle fuels under the volatile price of imported crude oil, the study illustrates the unstable margin caused by China's current pricing policy, which causes a distorted price signal and fiscal risks. The key findings derived from the empirical study reveal that the WTT cost is an essential guide for altering the vehicle fuel price with the aim of not only smoothing the impacts caused by the volatile price of crude oil price but also reflecting the correct oil price signal and reducing the fiscal risks.

13/03186 An evaluation framework for oil import security based on the supply chain with a case study focused on China

Zhang, H.-Y. *et al. Energy Economics*, 2013, 38, 87–95.

The import risks confronting oil consumers are influenced by transport conditions, oil prices, geopolitics, etc. This paper constructs an evaluation framework for oil import security from a perspective of supply chain process, and builds a two-phase data envelopment analysis-like model to evaluate oil import security. China is taken as an example to measure its oil import security during 1993–2011 and to identify the main risk factors in different periods. Results indicate that China's oil import risks have kept rising since 1993 and face multiple potential threats from each stage of oil import supply chain, among which the threat from external dependence has become the biggest challenge. Under different economic situations and changing energy environment, the risk factors affecting China's oil import security switched among different stages of the supply chain, showing a phase-transitioning characteristic from import over-dependence to increasing external supply pressure. The threat of external supply has become a new risk since the pressure of decreasing availability of external resource rose.

13/03187 An intelligent algorithm for performance evaluation of job stress and HSE factors in petrochemical plants with noise and uncertainty

Azadeh, A. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 140–152.

This study presents an intelligent algorithm based on adaptive neuro-fuzzy inference system (ANFIS) and statistical methods for measuring job stress in noisy and complex petrochemical plants. Job stress is evaluated against health, safety, environment and ergonomics (HSEE) program in the integrated algorithm. The algorithm is composed of seventeen distinct steps. To achieve the objectives of this study, standard questionnaires with respect to HSEE are completed by operators. The average results for each category of HSEE are used as inputs and job stress is used as output for the algorithm. Moreover, operators' stress level with respect to HSEE is evaluated by the algorithm. Finally, operators with weak stress level are identified. The advantage and superiority of the intelligent algorithm are shown by error analysis in contrast with conventional regression approaches. This is the first study that introduces an integrated intelligent algorithm for assessment and improvement of job stress and HSEE in noisy, complex and uncertain environment.

13/03188 An ontology-based framework for process monitoring and maintenance in petroleum plant

Elhdad, R. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 104–116.

In production plants, monitoring and maintaining industrial processes and emergency shutdowns are not straightforward tasks due to the large number of events and alarms which are triggered during the plant shutdown process. It is also vitally important to provide decision support to stakeholders for efficient and effective monitoring and maintenance of production process. This paper presents a novel framework and design to enhance maintenance decisions based on the knowledge gathered through the process of monitoring. This monitoring process is based on signals that are triggered during the plant safety shutdown process. The authors have designed and implemented a framework using an ontology and business rules to define the logical structure and operation of the petroleum plant with the objective of monitoring the cause and effect of the petroleum plant shutdown process. To enhance maintenance decisions, the authors have extended the ontology and the framework to ensure that decision makers have sufficient information to make the right decision at the right time. The proposed extended framework is designed, implemented and evaluated using an example petroleum production plant as a case study.

13/03189 Assessing the U.S. oil security premium

Brown, S. P. A. and Huntington, H. G. *Energy Economics*, 2013, 38, 118–127.

World oil supply disruptions lead to US economic losses. Increased oil consumption increases the vulnerability of the economy to oil supply disruptions, but it matters where the additional oil is produced. Increased production from stable producers can dampen future oil price shocks, whereas increased production from unstable producers can exacerbate future oil price shocks. Because oil is fungible, US pricing and import policies can differentiate only between domestic and imported oil rather than between stable and unstable sources. The economic losses associated with oil supply disruptions – gross domestic product losses and some transfers abroad – are externalities that can be quantified as oil security premiums. This study estimates these premiums by taking into account projected world oil market conditions, probable oil supply disruptions, the market response to oil supply disruptions, and the resulting US economic losses.

13/03190 Hurricane forecast revisions and petroleum refiner equity returns

Fink, J. D. and Fink, K. E. *Energy Economics*, 2013, 38, 1–11.

This study tests the return reaction of an index of petroleum refining firms to the official forecast revisions for major tropical storms in the refinery-dense region of the north-west Gulf of Mexico. First, it was found that improvements in official hurricane forecasts over the last 20 years have had a direct effect on when asset prices react in anticipation of tropical storms. In the 1990s, traders react to forecasts at the 24-hour horizon. A decade later they react earlier – price movements in the 2000s react to forecast information at the 48-hour horizon. Second, it was found that the effect of upward revisions in storm intensity is associated with increases in the returns to the index. These increases only accrue to large firms, perhaps due to these firms' ability to utilize geographic diversification and previously idle capacity to take advantage of storm-induced increases in refined petroleum prices.

13/03191 Oil consumption and output: what causes what? Bootstrap panel causality for 49 countries

Chu, H.-P *Energy Policy*, 2012, 51, 907–915.

This study examines the growth, conservation, neutrality and feedback hypotheses for 49 countries during the period from 1970 to 2010 using panel causality analysis: this technique accounts for both dependence and heterogeneity across the countries. The results provide evidence as to the direction of causality between oil consumption and output and are consistent with the neutrality hypothesis for 24 countries, the growth hypothesis for five countries, the conservation hypothesis for 13 countries, and the feedback hypothesis for seven countries. The findings provide important policy implications for the 49 countries under study.

13/03192 Spatiotemporal analysis of ethanol market penetration

Du, X. and Carriquiry, M. A. *Energy Economics*, 2013, 38, 128–135.

Consumption of ethanol in the USA has increased rapidly over the last few years, fuelled by both higher crude oil prices and generous public support measures for renewable fuels. The contribution of ethanol to the transport energy mix varies markedly by state. Heterogeneity in ethanol adoption and market development is investigated using a hierarchical, spatiotemporal model. A Bayesian Markov chain Monte Carlo method is employed for estimation of the proposed flexible model structure. Besides spatial dependence among neighbouring states, differential inclusion rates of ethanol are found to be largely determined by national- and state-level biofuel incentive policies, relative gasoline prices, feedstock availability, household median income, MTBE bans, and density of fuel retail infrastructure. The findings imply that increasing renewable fuel support as well as investing in extending the transportation and fuel retail infrastructure can result in higher ethanol consumption.

13/03193 The application of analytical network process to environmental prioritizing criteria for coastal oil jetties site selection in Persian Gulf coasts (Iran)

Hasanzadeh, M. *et al. Ocean & Coastal Management*, 2013, 73, 136–144.

Oil jetties are among the most effective land structures, which have cause a different potential for coastal environment destruction. These effects relate to the oil products of these industries that cause extensive oil pollution in coastal regions. Thus, the identification and prioritization of important criteria in site surveying of oil jetties are among the initial steps in preventing the loss of these natural resources. Therefore, the analytical network process (ANP) method was used for this purpose for the first time in Iran. Due to considering feedbacks and interrelations among all used elements of decision making process, ANP is considered an appropriate technique in environmental researches. After screening the selected criteria using Delphi, all criteria were distributed in BOCR merits according to their effects on oil jetties' location. Then, pair comparisons were done among the criteria, based on the ANP method. The prioritized criteria showed that 'compatibility with land uses' and 'sensitive coastal area' have the most and 'human population' and 'possibility for port development' the least global priority among all. The priority of alternatives is determined under the effect of each criterion. Finally, the suggested linear model through ANP findings showed a high efficiency of this method for ranking the important criteria of environmental construction in coastal regions, especially for oil jetties.

Derived liquid fuels

13/03194 A simple, reliable and fast algorithm for the simulation of multicomponent distillation columns

Monroy-Loperena, R. and Vacahern, M. *Chemical Engineering Research and Design*, 2013, 91, (3), 389–395.

This work has developed a simple, reliable and fast algorithm for the simulation of multicomponent distillation columns, where any equilibrium stage can accept a feed-stream and/or a vapour-side-stream and/or liquid-side-stream. The new scheme considers internal molar overflows and constant relative volatilities to avoid the need of heat balances and vapour–liquid equilibrium calculations. The solution scheme is founded on a Newton-based formulation in block algebra, which relies in a simple, reliable and fast algorithm. Although the proposed calculation scheme can be classified as an approximate method, it is very useful when accurate phase equilibrium and enthalpy data are lacking. Numerical experimentations show good agreement with the results obtained with well-known rigorous simulation approaches.

13/03195 Comparison of the yields and structure of fuels derived from freshwater algae (torbanite) and marine algae (El-Lajjun oil shale)

Amer, M. W. *et al. Fuel*, 2013, 105, 83–89.

Reactions of a Jordanian El-Lajjun oil shale under N_2 or H_2 for 1 h results in almost complete conversion of the organic material to liquid products at 355 or 390 °C. In contrast, reactions for 1 h of the algal coal, torbanite, give minimal conversion at 390 °C, but almost total conversion if the reaction time is extended to 5 h. At 355 °C reactions of torbanite are minimal at 1 and 5 h reaction times, however at 425 °C for 1 h almost complete conversion is observed. In addition, the oil to asphaltene ratio for the products from the Jordanian oil shale increases in the temperature range 355–390 °C, whereas the oil to asphaltene ratio for the products from torbanite strongly favours oil at all temperatures. The oil from both materials is highly aliphatic. The torbanite oil is mainly long chain, saturated hydrocarbons with few aromatic compounds. The oil from the Jordanian shale also has a high aliphatic content but a much wider range of aromatics. In addition, significant amounts of sulfur-containing compounds are present.

13/03196 Experimental investigation of performance, emission and combustion characteristics of an indirect injection multi-cylinder CI engine fuelled by blends of de-inking sludge pyrolysis oil with biodiesel

Hossain, A. K. *et al. Fuel*, 2013, 105, 135–142.

De-inking sludge can be converted into useful forms of energy to provide economic and environmental benefits. In this study, pyrolysis oil produced from de-inking sludge through an intermediate pyrolysis technique was blended with biodiesel derived from waste cooking oil, and tested in a multi-cylinder indirect injection type combustion injection (CI) engine. The physical and chemical properties of pyrolysis oil and its blends (20 and 30 vol.%) were measured and compared with those of fossil diesel and pure biodiesel (B100). Full engine power was achieved with both blends, and very little difference in engine performance and emission results were observed between 20% and 30% blends. At full engine load, the brake specific fuel consumption on a volume basis was around 6% higher for the blends when compared to fossil diesel. The brake thermal efficiencies were about 3–6% lower than biodiesel and were similar to fossil diesel. Exhaust gas emissions of the blends contained 4% higher CO_2 and 6–12% lower NO_x, as compared to fossil diesel. At full load, CO emissions of the blends were decreased by 5–10 times. The cylinder gas pressure diagram showed stable engine operation with the 20% blend, but indicated minor knocking with 30% blend. Peak cylinder pressure of the 30% blend was about 5–6% higher compared to fossil diesel. At full load, the peak burn rate of combustion from the 30% blend was about 26% and 12% higher than fossil diesel and biodiesel respectively. In comparison to fossil diesel the combustion duration was decreased for both blends; for 30% blend at full load, the duration was almost 12% lower. The study concludes that up to 20% blend of de-inking sludge pyrolysis oil with biodiesel can be used in an indirect injection CI engine without adding any ignition additives or surfactants.

13/03197 Long-term operation of biomass-to-liquid systems coupled to gasification and Fischer–Tropsch processes for biofuel production

Kim, K. *et al. Bioresource Technology*, 2013, 127, 391–399.

Long-term operation of the biomass-to-liquid (BTL) process was conducted with a focus on the production of bio-syngas that satisfies the purity standards for the Fischer–Tropsch (FT) process. The integrated BTL system consisted of a bubbling fluidized bed (BFB) gasifier (20 kW_{th}), gas cleaning unit, syngas compression unit, acid gas removing unit, and an FT reactor. Since the raw syngas from the gasifier contains different types of contaminants, such as particulates, condensable tars, and acid gases, which can cause various mechanical problems or deactivate the FT catalyst, the syngas was purified by passing through cyclones, a gravitational dust collector, a two-stage wet scrubber (packing-type), and a methanol absorption tower. The integrated system was operated for 500 h over several runs, and stable operating conditions for each component were achieved. The cleaned syngas contained no sulfur compounds (under 1 ppmV) and satisfied the requirements for the FT process.

13/03198 Methanol synthesis from syngas obtained by supercritical water reforming of glycerol

Gutiérrez Ortiz , F. J. *et al. Fuel*, 2013, 105, 739–751.

A process for producing methanol from the synthesis gas obtained by reforming of glycerol using supercritical water is studied. The process also produces power from the huge pressure energy of product gas just at the outlet of the reformer by a turbine. The expanded product gas is conditioned in a PSA system, which has three sections so as to produce a H_2-rich gas stream, a CO-rich gas stream and CO_2 for sequestration. Thus, it can be achieved the feed required for the methanol synthesis. The surplus hydrogen is sent to a fuel cell to generate power, and the PSA off-gas, purge from the methanol loop and gases separated from the crude methanol are burnt in a furnace to achieve an energy self-sufficient process. By changing the reforming temperature, the water-to-glycerol mass ratio and the purge from the methanol loop, the conditions for optimizing the overall process relative to methanol and power productions were achieved. Thus, by reforming at 1000 °C and 240 atm, and performing the methanol synthesis at 250 °C and 85 atm, the optimal conditions were a water-to-glycerol mass ratio of 1.68 with a purge ratio of 0.2. Under these conditions 0.270 kg MeOH/kg glycerol and overall energy efficiency of 38.0% were obtained. The separated CO_2 for sequestration is 0.38 kg/kg of glycerol.

13/03199 Performance and energy economics of mesophilic and thermophilic digestion in anaerobic hybrid reactor treating coal wastewater

Ramakrishnan, A. and Surampalli, R. Y. *Bioresource Technology*, 2013, 127, 9–17.

Two anaerobic hybrid reactors (AHR), mesophilic (35 °C) and thermophilic (55 °C) were operated with coal wastewater at different hydraulic retention times (HRT) ranging from 3–0.5 to 3.12–0.6 d with organic loading rates (OLR) of 1.12–6.72 $\mathrm{g\,L^{-1}\,d^{-1}}$. Synthetic coal wastewater with an average chemical oxygen demand (COD) of 2240 $\mathrm{mg\,L^{-1}}$ and phenolics concentration of 752 $\mathrm{mg\,L^{-1}}$ was used as substrate. At each HRT, the thermophilic AHR gave a better performance, measured in terms of phenolics/COD removal and gas production. The specific methane yield was also higher for thermophilic AHR at each HRT compared to mesophilic one. The volatile fatty acid concentration in the effluent increased with the lowering of HRT. The Stover–Kincannon model was applicable at both temperatures and showed higher substrate utilization in thermophilic AHR. Energy economic study of the AHRs revealed that 11,938 $\mathrm{MJ\,d^{-1}}$ more energy can be generated using thermophilic AHR than mesophilic.

13/03200 Simulation of vapor flows in short path distillation

Hu, H. *et al. Computers & Chemical Engineering*, 2013, 49, 127–135.

Based on the direct simulation Monte Carlo (DSMC) method, one- and two-dimensional models of vapour flows in the short path distillation are established. To reflect the reality, molecular rotation is included in this study and a reasonable boundary condition is introduced. The simulations are tested by comparison with the previous experiment, which shows that the distillation rate and composition are closer to the experiment compared to the previous models, and the simulated temperature field is higher than that of the previous models. The agreements between experimental and simulated results show that the models represent well the phenomena that occur in the vapour space of the short path distillatory. Based on the revised model, macroscopic variables related to a particular position in the distillation gap are analysed in detailed. Furthermore, dependence of the evaporation efficiency on the ratio of condensing area to evaporating area and influence of inert gas on the distillation process are investigated.

13/03201 Synthesis and characterization of ethylic biodiesel from animal fat wastes

Cunha, A. *et al. Fuel*, 2013, 105, 228–234.

This study optimized the conversion of animal fat wastes into ethylic biodiesel by alkali-catalysed process under mild conditions. A mix of chicken and swine fat residues was used as feedstock for biodiesel production. A full 3^3 factorial design was used to optimize process parameters for maximum fatty acid ethyl esters yield. Factors were evaluated at three different levels: temperature (30, 50 and 70 °C), ethanol to fat molar ratio (6:1, 7:1 and 8:1) and catalyst concentration (0.44, 0.88 and 1.32 wt%). Effects of the process variables were analysed using response surface methodology. Moreover, optimum conditions were applied in a bench-scale reactor and biofuel produced was characterized. It was observed that at high temperatures (50 and 70 °C), phase separation between biodiesel and glycerol was impaired. Although high conversion was achieved (96.2%) at 70 °C, this condition is not recommended because no spontaneous phase separation was verified. On the other hand, 30 °C was identified as the best temperature for biodiesel ethanolysis, using 0.96 wt% catalyst and 7:1 ethanol to fat molar ratio. With these conditions, it is possible to achieve around 83% conversion. Despite the oxidative stability and total glycerin, biodiesel measured properties agreed with quality requirements established by official regulations (ASTM 6751 and EN 14214).

03 GASEOUS FUELS

Sources, properties, recovery, treatment

13/03202 A comparative experimental study of the interactions between platinum and a range of hydrocarbon fuels

Badra, J. *et al. Fuel*, 2013, 105, 523–534.

This paper presents the reactivity of different alkanes ranging from C_1 to C_4 over platinum. The four fuels used are compressed natural gas (CNG), liquefied petroleum gas (LPG), butane, and ethane. Experiments are performed to study the effects of varying the temperature of the incoming mixture (T_{jet}), its equivalence ratio (φ) and the Reynolds number (Re), on the reactivity limits and species distributions. Platinum surface temperatures as well as species profiles streamwise and transverse to the plate are investigated. The reactivity limits of ethane over platinum are discussed in details. For flameless combustion (defined by the presence of reactions on the plate without a gaseous flame), it is found that the plate temperatures of ethane/air peak at moderately rich mixtures ($\varphi = 1.3$) and the reactivity limits broaden in the presence of platinum plate compared to the gaseous flammability limits. The main products of burning these four hydrocarbon fuels over platinum are CO_2 and H_2O while CNG showing the highest selectivity to CO and H_2. Species such as methane (CH_4), acetylene (C_2H_2), ethane (C_2H_6), dimethyl ether (C_2H_6O), propylene (C_3H_6), and propane (C_3H_8) appear in the products when burning LPG and butane over platinum. The streamwise profiles of species indicate the presence of two reacting zones along the plate which are described as: (i) the leading edge zone where high gradients of species mole fractions are observed and (ii) the trailing zone where the profiles are more flat and stable. The transverse profiles highlight the presence of two reactive layers: (i) the inner boundary where peaks of CO, CO_2, and H_2 occur and (ii) the outer layer where formation of the other hydrocarbons is observed. Heavier alkanes result in oxygen/fuel ratio near the plate higher than those injected in the free stream and this may be largely due to differential molecular as well as thermal diffusion.

13/03203 Gas hydrate and associated free gas in the Dongsha Area of northern South China Sea

Li, L. *et al. Marine and Petroleum Geology*, 2013, 39, (1), 92–101.

A large ongoing cold seep, called the Jiulong methane reef, was discovered in the Dongsha area of northern South China Sea (SCS) in 2004. To understand links among seafloor methane seepage, subsurface gas hydrate, origin of gas source and structural styles controlling the formation and accumulation of gas hydrate, high resolution multichannel seismic data were interpreted in this region. bottom simulating reflectors (BSRs), known as the base of gas hydrate stability zone, were identified and mapped. Additionally, seismic attributes, interval velocity model, and acoustic P-wave impedance were obtained to better delineate the spatial distribution of gas hydrate. Hydrate-bearing sediments are characterized by weak reflection (i.e. blanking zone) above BSRs, high velocities and relatively small acoustic impedance differences, while enhanced reflection, low frequency, and low velocities beneath BSRs suggest the presence of underlying free gas beneath solid hydrate. A number of faults, mud diapirs and a possible submarine landslide were observed in seismic profiles. Both faults and mud diapirs are useful conduits, allowing methane gas to migrate upward and linking free gas zones beneath BSRs, hydrate zones and seafloor methane seepage. A submarine landslide with a length scale of ~10 km is observed in a seismic profile. The landslide may trigger dissociation of gas hydrate, accounting for the occurrence of Jiulong methane seepage. Seismic observations and estimated heat flow coupled with geochemical analyses suggest that gas source of methane in this region probably originates from mixture of biogenic and thermogenic methane. This study would not only help to understand gas hydrate system in the Dongsha area, but also provide insights to geological hazards associated with the dissociation of gas hydrate.

13/03204 New type curves for analyzing horizontal well with multiple fractures in shale gas reservoirs

Nobakht, M. *et al. Journal of Natural Gas Science and Engineering*, 2013, 10, 99–112.

To produce economically from most shale gas plays, horizontal wells (cased or openhole) with multiple fractures are the most popular choice for completing the wells. A number of well-performance behaviours can be seen for these wells depending on reservoir behaviour and induced hydraulic-fracture geometry. In this paper, conceptual models for well/reservoir/hydraulic fracture combinations are presented and the impact of various reservoir types/induced hydraulic-fracture geometries upon the sequence of flow-regimes that could be encountered for shale gas reservoirs are considered. In addition, the authors develop and present new sets of dimensionless type-curves for one of the conceptual models. The newly developed type curves in this study yield more unique results than those presented previously. With these dimensionless type curves, the early linear flow (early-time half slope) and boundary-dominated flow (late-time unit slope) fall on top of each other and the transition between these two regimes depends on the geometry of the reservoir and completion. Using the type curves as a guide, the authors present the flow regimes that are expected for different values of horizontal well length, number of fractures, length of the fractures and spacing between horizontal wells. They also present a new method for evaluating the contribution from the outer reservoir (beyond the fracture length). Finally, using the characteristics of new dimensionless parameters and the new type-curve set, a simple and practical procedure is presented for long-term forecasting in multi-fractured horizontal wells.

13/03205 Recovery of CH_4 from coal mine model gas mixture (CH_4/N_2) by hydrate crystallization in the presence of cyclopentane

Zhong, D.-L. *et al. Fuel*, 2013, 106, 425–430.

This work presents how water containing cyclopentane (CP) can facilitate the recovery of methane from the CH_4/N_2 coal mine gas mixture through hydrate crystallization. Gas hydrate formed in the $CH_4/N_2/CP/H_2O$ system has more favourable equilibrium conditions than that formed in pure water with the same gas mixture. The incipient equilibrium conditions at 4.0 and 13.0 wt% CP were measured and are reported. The dynamics of hydrate formation using a 30 mol% CH_4/N_2 gas mixture were studied at 283.4 K, two CP concentrations (4.0 and 13.0 wt%) and at 2.6 and 3.8 MPa. These hydrate formation pressures correspond to 2.3 and 3.5 MPa overpressures (driving forces), respectively. It was found that CH_4 is preferentially incorporated into the hydrate crystal compared to N_2. However, N_2 competes with CH_4 to enter the hydrate crystal at the higher driving force. The CH_4 recovery substantially increases as the CP concentration is increased from 4.0 to 13.0 wt%. The experimental condition of 283.4 K, 2.6 MPa, and 13.0 wt% CP is preferred for the separation of CH_4 from the 30 mol% CH_4/N_2 gas mixture. The CH_4 recovery obtained at this condition is approximately 46.1% and the corresponding CH_4 content in the hydrate is 47.2 mol%. A methane-rich stream (72 mol% CH_4/N_2) is obtained after two stages of gas hydrate formation in the presence of cyclopentane.

13/03206 Rock characterization of Fayetteville shale gas plays

Bai, B. *et al. Fuel*, 2013, 105, 645–652.

Multiple techniques were used to characterize the petrophysical properties of the rock samples from the Fayetteville shale gas play, including clay mineralogy, wettability, organic matter and their maturation, submicron pore structure, and three-dimensional pore structure. X-ray diffraction mineralogy analysis showed high quartz and low clay content in the Fayetteville shale. Wettability tests revealed that the shale surface is originally intermediate-wet and the additives used in hydraulic fracturing fluids can alter shale gas surfaces toward water-wet conditions. The kerogen analysis suggested kerogen type IV and a high level of maturation in the tested samples. Three types of pores were observed through scanning electron microscopy (SEM) images and the majority of the pores in organic matters were submicron sized (5–100 nm). A three-dimensional pore structure model was reconstructed from 200 two-dimensional SEM/FIB images, and the rock petrophysical properties, including porosity, permeability, and tortuosity, were calculated from the model. In addition, a good agreement was found between the total organic carbon (TOC) computed from SEM images and the TOC measured in the laboratory.

Transport, storage

13/03207 An analytical model for desorption area in coal-bed methane production wells

Xu, B. *et al. Fuel*, 2013, 106, 766–772.

Production forecasting, well spacing, and well pattern optimization are key tasks in coal-bed methane field development plan. Desorption area around a production well is an important factor in well performance and reserve estimation. Analytical models are found to be simple and practical tools for drainage area calculation and well deliverability in conventional reservoirs. However, up to now, the authors have found no such analytical model for coal-bed methane wells with two-phase flow in which the gas desorption in coal is the controlling mechanism while the water is flowing in the cleat system. This paper presents a mathematical model to predict how the size of desorption area is changing with pressure propagation during gas and water production. The pressure profiles at different production stages are determined using diffusivity equation which is solved using the known method of ‘continuous succession of steady states’. For the case of two-phase flow of gas–water system, the pressure squared concept is used for linearization in middle and late times, while the pressure concept is used in early times when water flow is dominated. The authors have combined pressure from the solution of diffusivity equation with the material balance equation in order to develop the predictive model which is applicable for vertical wells for both cases of with or without hydraulic fractures. This model is verified by numerical simulation and is in excellent agreement with the numerical solutions. Furthermore, the developed model is applied in one coal-bed methane well group in Hancheng field in China. It is found that desorption area is expanded outward in elliptical shape and the area can be calculated by the gas production data. The results show that two sample wells in the group have interfered with each other after producing for 525 days.

13/03208 An integrated quantitative hazard analysis method for natural gas jet release from underground gas storage caverns in salt rock. I: models and validation

Yang, S. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 68–73.

It is very important and necessary to perform quantitative hazard analysis for possible accidental leakage from an underground gas storage cavern in salt rock. An integrated quantitative hazard analysis method for natural gas jet release from salt caverns is presented in this paper, which was constituted by a revised model for gas leakage rate calculation, a consequence analysis and a model of probability assessment for harm. The presented method was validated by comparing the analytical results with the data collected from the real accidents (including the leakage, jet fire, fireball and vapour cloud explosion). It is indicated that the proposed method was more accurate than the TNT equivalence method for vapour cloud explosion and gave more reasonable results when applied to the consequence analysis for the thermal radiation from jet fire and fireball.

13/03209 An integrated quantitative hazard analysis method for natural gas jet release from underground gas storage caverns in salt rock. II: a sample computation and parametric study

Yang, S. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 68–73.

It is of great importance and necessity to perform quantitative hazard analysis on possible accidental leakage from gas storage cavern in salt rock. To improve the working safety in the cavern, an integrated quantitative method for hazard analysis on natural gas jet release from caverns in salt rock was presented. In this paper, a sample of gas storage cavern in salt rock was analysed to demonstrate the presented method. Furthermore, the factors that influence the hazard range of leakage accidents from gas storage cavern in salt rock were discussed. The results indicated that the release rate diminishes with increased pipe length due to friction in steady-state. Meanwhile, the hazard distance from production casing also diminishes with increased pipe length. As the pipeline gets as long as several kilometres, the predicted hazard distance will be constant. However, the hazard distance increases with increasing the operating pressure and pipeline diameter.

13/03210 Exploration on process design, optimization and reliability verification for natural gas deacidizing column applied to offshore field

Tang, J. *et al. Chemical Engineering Research and Design*, 2013, 91, (3), 542–551.

Onshore acid gas purification technology and experience are extended to offshore situation in this paper. Deacidizing technique using mixed amine solvent of methyldiethanolamine (MDEA) and diethanolamine (DEA) is researched and applied into a specific offshore gas field. The process is simulated and analysed according to the parameter design and type selection of column which is the most important equipment on decks. Furthermore, the ranges of key parameters are proposed. Different process schemes are analysed comprehensively and the optimum parameters are selected using the method of five factors fuzzy industrial evaluation for column capability. The structure design of absorption column is also performed. Stress and strain changes are studied under different tilt angles and working conditions by ANSYS software. The reliability of column structure design is verified and the process solution for the specific gas field is optimized. The research can provide certain guidance and reference to natural gas deacidizing technology for offshore field.

13/03211 Linepack storage valuation under price uncertainty

Arvesen, Ø. *et al. Energy*, 2013, 52, 155–164.

Natural gas flows in pipelines as a consequence of the pressure difference at the inlet and outlet. Adjusting these pressures makes it possible to inject natural gas at one rate and withdraw at a different rate, hence using the pipeline as storage as well as transport. This paper considers the value of using the so-called pipeline linepack as a short-term gas storage and how this functionality may offset the discrepancy between the low flexibility in take-or-pay contracts and the high inherent flexibility of a gas-fired power plant. To value the storage option, the authors consider a cycling power plant facing volatile power prices while purchasing gas on a take-or-pay contract. They estimate a Markov regime-switching model for power prices and a mean reverting jump diffusion model for gas prices. Applying least squares Monte Carlo simulation to the operation of the linepack storage, it was found that the storage option indeed has significant value for the plant, enabling it to better exploit the sometimes extreme price fluctuations. Finally, the authors show how power price volatility and jump frequency are the main value drivers, and that the size of the storage increases the value up to a point where no additional flexibility is used.

13/03212 Monitoring groundwater flow and chemical and isotopic composition at a demonstration site for carbon dioxide storage in a depleted natural gas reservoir

de Caritat, P. *et al. Applied Geochemistry*, 2013, 30, 16–32.

Between March 2008 and August 2009, 65,445 tonnes of ~75 mol% CO_2 gas were injected in a depleted natural gas reservoir approximately 2000 m below surface at the Otway project site in Victoria, Australia. Groundwater flow and composition were monitored biannually in two overlying aquifers between June 2006 and March 2011, spanning the pre-, syn- and post-injection periods. The shallower (~0–100 m), unconfined, porous and karstic aquifer of the Port Campbell limestone and the deeper (~600–900 m), confined and porous aquifer of the Dilwyn Formation contain valuable fresh to brackish water resources. Groundwater levels in either aquifer have not been affected by the drilling, pumping and injection activities that were taking place, or by the rainfall increase during the project. In terms of groundwater composition, the Port Campbell limestone groundwater is brackish (electrical conductivity = $801–3900\,\mu S\,cm^{-1}$), cool (temperature = 12.9–22.5 °C), and near-neutral (pH = 6.62–7.45), while the Dilwyn Aquifer groundwater is fresher (electrical conductivity = $505–1473\,\mu S\,cm^{-1}$), warmer (temperature = 42.5–48.5 °C), and more alkaline (pH = 7.43–9.35). Carbonate dissolution, evapotranspiration and cation exchange control the composition of the groundwaters. Comparing the chemical and isotopic composition of the groundwaters collected before, during and after injection shows no statistically significant changes; even if they were statistically significant, they are mostly not consistent with those expected if CO_2 addition had taken place. The monitoring programme reveals no impact on the groundwater resources that are attributable to the C storage demonstration project.

13/03213 Predicting temperature distribution in the waxy oil-gas pipe flow

Duan, J. *et al. Journal of Petroleum Science and Engineering*, 2013, 101, 28–34.

In the simulation of waxy oil–gas pipeline multiphase flow, the physical parameters and rheological properties of the multiphase fluid are the sensitivity functions of the temperature. The precise temperature distribution of multiphase fluid is the foundation of predicting the pressure distribution accurately, wax deposition rate, optimized design and operating analysis of waxy oil and gas pipeline, and so on. Based on the energy equation of oil–gas flow in pipeline, the explicit temperature drop formula for oil–gas steady state calculation is derived from the energy conservation analysis in micro-element. This new energy equation has considered many factors, such as heat transfer with the surroundings along the line, Joule–Thomson effect and impact of terrain undulation to potential energy. So it is an overall form of energy equation, which could reflect the actual fact of multiphase pipeline accurately. Elimination of temperature iteration loop and integration of the explicit temperature equation, instead of enthalpy energy equation, into the conjugated hydraulic and thermal computation have been found to improve the efficiency of algorithm. The calculation program of temperature drops of waxy oil–gas flow in pipelines is compiled on the basis of the explicit temperature drop formula employing modification of the specific heat of the waxy oil. This model is carried out with a practical waxy oil–gas two phase flow pipeline, and the temperature results are compared with OLGA. It is shown that this model has simulated the temperature distribution very well.

13/03214 Simulation of gas–solid two-phase flow in the annulus of drilling well

Hajidavalloo, E. *et al. Chemical Engineering Research and Design*, 2013, 91, (3), 477–484.

This paper investigates the hydrodynamic behaviour of gas–solid two-phase flow in the annular space of an air drilling well under different arrangements by using three-dimensional approach. Two-fluid model is used to solve the governing equations in the Eulerian–Eulerian framework. Effect of eccentricity and drill pipe rotation on the pressure drop, volume fraction and velocity profile are examined. The results are compared with available data in the literature and good agreement is found. The results show that the presence of solid particles in the annulus change the air velocity profile significantly and create two off-centre peaks velocity close to the walls instead of one peak velocity in the middle. Eccentricity of drill pipe makes more accumulation of the cuttings in the smaller space of the annulus. Increasing the eccentricity increases pressure drop due to impact of particles with annulus wall and also particles collision with each other. Rotation of the drill pipe shifts maximum air velocity location toward smaller space of the annulus which results more uniform cutting distributions in the annulus and improvement in their transportations. Pressure drop in the annulus increases as eccentricity and rotation of drill pipe increase.

13/03215 Wax formation assessment of condensate in South Pars gas processing plant sea pipeline (a case study)

Rahimpour, M. R. *et al. Journal of Natural Gas Science and Engineering*, 2013, 10, 25–40.

The wax deposition from the gas condensate in South Pars gas processing plant causes a number of severe problems. These problems include: (1) deposits form on the reboiler tubes of stabilizer column and tend to reduce its duty; (2) forcing periodic shut-down and removal of deposits and (3) interrupting normal processing operations. An understanding of deposition, nature and propensity is necessary to mitigate the mentioned problems. In this work, the multi-solid phase model is used to predict the wax precipitation from gas condensate fluid. For five different reservoir fluids, several methods were investigated to split the heavy hydrocarbon fraction into pseudo fractions. The results show that the Al-Meshari method is the most accurate one. Also, a set of consistent correlations were used to calculate the critical points, fusion properties and the acentric factor of the single carbon number groups in the extended composition. Finally the best methods for predicting the wax formation are selected and used to predict the wax formation in the sea line of South Pars gas processing plant. The modelling shows that wax precipitation starts at 293 K and 86 bar. At this pressure and temperature the pipeline is 94 km away from the wellhead.

Economics, business, marketing, policy

13/03216 A safety barrier-based accident model for offshore drilling blowouts

Xue, L. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 164–171.

Blowout is one of the most serious accidents in the offshore oil and gas industry. Accident records show that most of the offshore blowouts have occurred in the drilling phase. Efficient measures to prevent, mitigate, and control offshore drilling blowouts are important for the entire offshore oil and gas industry. This article proposes a new barrier-based accident model for drilling blowouts. The model is based on the three-level well control theory, and primary and secondary well control barriers and an extra well monitoring barrier are established between the reservoir and the blowout event. The three barriers are illustrated in a graphical model that is similar to the well-known Swiss cheese model. Five additional barriers are established to mitigate and control the blowout accident, and event tree analysis is used to analyse the possible consequence chains. Based on statistical data and literature reviews, failures of each barrier are presented. These failures can be used as guidance for offshore drilling operators to become aware of the vulnerabilities of the safety barrier system, and to assess the risk related to these barriers. The Macondo accident is used as a case study to show how the new model can be used to understand the development of the events leading to the accident. The model can also be used as an aid to prevent future blowouts or to stop the escalation of events.

13/03217 A simulation approach for analysis of short-term security of natural gas supply in Colombia

Villada, J. and Olaya, Y. *Energy Policy*, 2013, 53, 11–16.

Achieving security of gas supply implies diversifying gas sources, while having enough supply, transportation, and storage capacity to meet demand peaks and supply interruptions. Devising a strategy for securing gas supply is not straightforward because gas supply depends on complex interactions of production, demand and infrastructure, and it is exposed to economic, regulatory, political, environmental and technical risks. To address this complexity, the authors propose a simulation approach that replicates the structure of the gas supply chain, including transportation constraints and demand fluctuations. They build and calibrate a computer model for the Colombian gas sector, and run the model to assess the impact of expanding transportation capacity and increasing market flexibility on the security of supply. The analysis focuses on the operation and planned and proposed expansions of the transportation infrastructure because adequate regulation and development of this infrastructure can contribute to increase the security of supply in the gas sector. The authors find that proposed import facilities, specifically LNG import terminals at Buenaventura, increase system's security under the current market structure.

13/03218 Energy (in)security in Poland the case of shale gas

Johnson, C. and Boersma, T. *Energy Policy*, 2013, 53, 389–399.

The large-scale extraction of natural gas from shale rock layers in North America using hydraulic fracturing, or 'fracking', has prompted geologists, economists and politicians in various parts of the world to ask whether there are new reserves of this precious resource to be found under their soils. It has also raised a host of questions about the potential environmental impacts of extracting it. Drawing on research on both sides of the Atlantic, this paper assesses the most pressing issues for research and policy makers related to shale gas extraction. The paper provides a survey of environmental and economic issues related to shale gas and then turns to a case study of Poland, whose policy makers have been among the most fervent proponents of shale gas development in the European Union. What stands out in the Polish case is that even under favourable geologic and market conditions, there are substantial infrastructural, political and regulatory hurdles to be overcome. At least part of the key to shale gas development therefore seems to lie in the halls of government of Warsaw. While this paper has assessed some of the larger-scale issues in the economic and political environments in Poland, the European Union, and beyond, the authors were not in a position to assess local challenges to shale gas development. North Americans, at least those in places such as Texas, Oklahoma, and Alberta, are largely accustomed to hydrocarbon extraction and the resulting disturbances to the landscape, noise pollution, in combination with substantial royalty checks (at least in the USA), but the same cannot be said of those living in the regions where shale gas development would likely take place in Poland. Public opposition there has so far been barely visible, but so has the extent of exploratory drilling. The lack of public opposition is likely related to a combination of factors, including the historical tensions and mistrust between Poland and Russia, but it is too early to assess to what extent the Polish public would welcome large scale shale gas development.

13/03219 Experimental research on performance response of domestic gas cookers to variable natural gas constituents

Zhang, Y. *et al. Journal of Natural Gas Science and Engineering*, 2013, 10, 41–50.

In China, the imported liquefied natural gas (LNG) has been steadily increased in past years, with its constituents different from those of traditional pipeline natural gases (PNG) to various extents. In this paper several natural gases to be delivered to Guangdong provinces in China were selected as test gases to measure performance response of 17 sets of domestic gas cookers. Heat input rating, CO and NO$_x$ emission, and thermal efficiency was measured according to related national standards. American Gas Association indexes and Weaver indexes were used to predict combustion stability and emission under different gas constituents. Experiment results were compared with prediction to analyse the applicability of the two well-established indexes systems. It was concluded that Wobbe index can predict heat input rating quite accurately, and CO and NO$_x$ emissions can be remained with reasonable limits for the changing constituents discussed. For combustion stability prediction, judgement criteria should be adjusted as follows: Weaver lifting index from $J_L \geq 0.64$ to $J_L \geq 0.95$, Weaver incomplete combustion index from $J_I \leq 0.05$ to $J_I \leq 0.04$, and AGA lifting index from $I_L \leq 1.10$ to $I_L \leq 1.05$.

13/03220 Governing transitions: cases and insights from two periods in the history of the UK gas industry

Arapostathis, S. *et al. Energy Policy*, 2013, 52, 25–44.

The paper aims to inform historically the analyses of future socio-technical transition pathways in the electricity sector, particularly those developed by the 'Transition pathways to a low carbon economy' project. It also aims to inform the theoretical approach to transitions by focusing on key decisions at 'branching points' that led to transitions in the UK gas energy services regime, which occurred under different governance patterns. The first historical case study covers the market-led transformation of the manufactured gas regime from 1877 to 1914, which developed the end-uses of gas beyond lighting to include cooking, and extended access to working-class consumers. The second case study covers the period from 1948 to 1977, historically reconstructing the transition from town gas to natural gas. This state-led and co-ordinated conversion to natural gas was preceded by a period of destabilization of the manufactured gas regime, the co-existence of several niche technologies and the hybridization of the key actors and technological infrastructures of the incumbent regime. Comparing the cases provides insights for future energy service transitions by addressing the significance of power, trust and networking in the decision making processes involved in the governance of energy transitions.

13/03221 Main drivers of natural gas prices in the Czech Republic after the market liberalisation

Slabá, M. *et al. Energy Policy*, 2013, 52, 199–212.

One of the goals of the European Commission in the energy sector is creating a single competitive European market. The decision to liberalize energy markets has far-reaching consequences not only for gas companies, but also for the rest of the real economy in view of the fact that natural gas is being used as an important primary energy source in several sectors of production and in the power industry. The authors aim to answer how liberalization/unbundling has influenced gas pricing/prices in the Czech Republic. They investigate the individual components of end-customer gas prices according to the value chain as well as define and structure the drivers of these components. A case study is used from the Czech Republic, one of the central and eastern European countries, which, contrary to the old member states, is buying most of its gas from one supplier (high import dependence and low supply diversity) and where the transmission and distribution network is characterized by a sufficient contractual and physical capacity. The authors stress that next to basic conditions on the European gas market (import dependency on external gas producers) legal and institutional conditions and the initial market structure of each member state are also important for the results of the liberalization.

13/03222 The competitiveness of synthetic natural gas as a propellant in the Swedish fuel market

Mohseni, F. *et al. Energy Policy*, 2013, 52, 810–818.

The road transport sector today is almost exclusively dependent on fossil fuels. Consequently, it will need to face a radical change if it aims to switch from a fossil-based system to a renewable-based system. Even though there are many promising technologies under development, they must also be economically viable to be implemented. This paper studies the economic feasibility of synthesizing natural gas through methanation of carbon dioxide and hydrogen from water electrolysis. It is shown that the main influences for profitability are electricity prices, synthetic natural gas (SNG) selling prices and that the by-products from the process are sold. The base scenario generates a 16% annual return on investment assuming that SNG can be sold at the same price as petrol. A general number based on set conditions was that the SNG must be sold at a price about 2.6 times higher per kWh than when bought in form of electricity. The sensitivity analysis indicates that the running costs weigh more heavily than the yearly investment cost and off-peak production can therefore still be economically profitable with only a moderate reduction of electricity price. The calculations and prices are based on Swedish prerequisites but are applicable to other countries and regions.

13/03223 The feasibility of CO$_2$ storage in the depleted P18-4 gas field offshore the Netherlands (the ROAD project)

Arts, R. J. *et al. International Journal of Greenhouse Gas Control*, 2012, 11, (Supplement), S10–S20.

Near the coast of Rotterdam CO$_2$ storage in the depleted P18-4 gas field is planned to start in 2015 as one of the six selected European demonstration projects under the European Energy Programme for Recovery (EEPR). This project is referred to as the ROAD project. ROAD (a Dutch acronym for Rotterdam Capture and Storage Demonstration project) is a joint project by E.ON Benelux and Electrabel Nederland/GDF SUEZ Group and is financially supported by the European Commission and the Dutch state. A post-combustion carbon capture unit will be retrofitted to EONs' Maasvlakte power plant 3 (MPP3), a new 1100 MWe coal-fired power plant in the port of Rotterdam. The capture unit has a capacity of 250 MWe equivalent and aims to capture 1.1 million tonnes of CO$_2$ per year. A 20 km long insulated pipeline will be constructed to the existing offshore platform operated by TAQA and an existing well will be worked over and reused for injection. Natural gas production in the P18-4 field is projected to end just before the start of the CO$_2$ injection. In this first phase a total storage of around 5 Mt CO$_2$ is envisaged with an injection timeframe of 5 years. This paper gives a description of the field and of the studies carried out to investigate the suitability of the field for CO$_2$ storage.

13/03224 The relationship between spot and contract gas prices in Europe

Asche, F. *et al. Energy Economics*, 2013, 38, 212–217.

Following deregulations in the European gas market, spot trading of natural gas has been established in the UK, Belgium and the Netherlands, while long-term contracts remain the dominant pricing process in continental Europe. This paper investigates the degree of market integration between the three spot markets, the contract gas price in Germany and the oil price. The results indicate a highly integrated market, and there is no evidence of an independent price determination process for natural gas.

13/03225 Thermoeconomic assessment of a natural gas expansion system integrated with a co-generation unit

Kostowski, W. J. and Usón, S. *Applied Energy*, 2013, 101, 58–66.

Interest in turboexpander installations for the natural gas industry is increasing. However, turboexpander projects are still characterized by an insufficient economic feasibility and a long pay-back period. The use of co-generation, as in the system analysed in this paper, is a promising approach for improving these issues. The thermoeconomic analysis can help engineers designing such systems to improve their thermodynamic quality. The calculations of energy performance show a relatively high performance ratio. However, the exergy efficiency is a more suitable indicator because it properly takes into account the effect of gas pressure and it has the upper limit of 100%. Its value obtained for the case study (49.2%) is not a bad figure but indicates that there is a potential for improvement. Furthermore, thermoeconomic analysis performed points out in which components this potential is higher. Since the unit cost of electricity produced in turboexpanders ($k^* = 2.33$) is higher than the unit cost of electricity generated in the CHP module ($k^* = 1.33$), attention should be focused on the former. More detailed analysis shows that the high cost of electricity results from the inefficient gas pre-heating system, where heat transfer is carried out through significant temperature differences. The high temperature of the exhaust gases is used for the final purpose of increasing the natural gas temperature from about 10 °C to only 70–80 °C. Accordingly, although the use of co-generation represents a good advantage compared to the use of boilers, it is recommended to reduce this negative effect, e.g. by applying low temperature heat sources for gas pre-heating. It should be noted that these conclusions can only be obtained by using exergy analysis, since the energy efficiency of heat exchangers is assumed 100%. Finally, the system is characterized by low values of carbon dioxide emissions, which will even decrease if efficiency of the system increases due to improvements in subsystems pointed out by the analysis developed in this work.

13/03226 Toward the integration of European natural gas markets: a time-varying approach

Renou-Maissant, P. *Energy Policy*, 2012, 51, 779–790.

Over the past 15 years, European gas markets have radically changed. In order to build a single European gas market, a new regulatory framework has been established through three European gas directives. The purpose of this article is to investigate the impact of the reforms in the natural gas industry on consumer prices, with a specific focus on gas prices for industrial use. The strength of the relationship between the industrial gas prices of six western European countries is studied by testing the law of one price for the period 1991–2009. Estimations were carried out using both cointegration analysis and time-varying parameter models. Results highlight an emerging and on-going process of convergence between the industrial gas prices in western Europe since 2001 for the six European Union member states. The strength and the level of convergence differ widely between countries. Strong integration of gas markets in continental Europe, except for the Belgian market, has been established. It appears that the convergence process between continental countries and the UK is not completed. Thus, the integration of European gas markets remains an open issue and the question of how far integration will proceed will still be widely discussed in the coming years.

Derived gaseous fuels

13/03227 Analysis of hollow fibre membrane systems for multicomponent gas separation

Khalilpour, R. *et al. Chemical Engineering Research and Design*, 2013, 91, (2), 332–347.

This paper analysed the performance of a membrane system over key design/operation parameters. A computation methodology is developed to solve the model of hollow fibre membrane systems for multicomponent gas feeds. The model represented by a non-linear differential algebraic equation system is solved via a combination of backward differentiation and Gauss–Seidel methods. Natural gas sweetening problem is investigated as a case study. Model parametric analyses of variables, namely feed gas quality, pressure, area, selectivity and permeance, resulted in better understanding of operating and design optima. Particularly, high selectivities and/or permeabilities are shown not to be necessary targets for optimal operation. Rather, a medium selectivity (<60 in the given example) combined with medium permeance ($\sim 300–500 \times 10^{-10}$ mol/s m^2 Pa in the given case study) is more advantageous. This model-based membrane systems engineering approach is proposed for the synthesis of efficient and cost-effective multi-stage membrane networks.

13/03228 Catalytic conversion wood syngas to synthetic aviation turbine fuels over a multifunctional catalyst

Yan, Q. *et al. Bioresource Technology*, 2013, 127, 281–290.

A continuous process involving gasification, syngas cleaning, and Fischer–Tropsch (FT) synthesis was developed to efficiently produce synthetic aviation turbine fuels (SATFs). Oak-tree wood chips were first gasified to syngas over a commercial pilot plant downdraft gasifier. The raw wood syngas contains about 47% N_2, 21% CO, 18% H_2, 12% CO_2, 2% CH_4 and trace amounts of impurities. A purification reaction system was designed to remove the impurities in the syngas such as moisture, oxygen, sulfur, ammonia, and tar. The purified syngas meets the requirements for catalytic conversion to liquid fuels. A multifunctional catalyst was developed and tested for the catalytic conversion of wood syngas to SATFs. It was demonstrated that liquid fuels similar to commercial aviation turbine fuels (Jet A) was successfully synthesized from bio-syngas.

13/03229 Selective catalytic oxidation of ammonia by nitrogen oxides in a model synthesis gas

Tunå, P. and Brandin, J. *Fuel*, 2013, 105, 331–337.

Synthesis gas generated by the gasification of nitrogen-containing hydrocarbons will contain ammonia. This is a catalyst poison and elevated levels of nitrogen oxides (NO_x) will be produced if the synthesis gas is combusted. This paper presents a study of the selective oxidation of ammonia in reducing environments. The concept is the same as in traditional selective catalytic reduction, where NO_x are removed from flue gas by reaction with injected ammonia over a catalyst. Here, a new concept for the removal of ammonia is demonstrated by reaction with injected NO_x over a catalyst. The experiments were carried out in a model synthesis gas consisting of CO, CO_2, H_2, N_2 and NH_3/NO_x. The performance of two catalysts, $V_2O_5/WO_3/TiO_2$ and H-mordenite, were evaluated. On-site generation of NO_x by nitric acid decomposition was also investigated and tested. The results show good conversion of ammonia under the conditions studied for both catalysts, and with on-site generated NO_x.

13/03230 Simulation study and kinetic parameter estimation of underground coal gasification in Alberta reservoirs

Kariznovi, M. *et al. Chemical Engineering Research and Design*, 2013, 91, (3), 464–476.

A new method is developed for the estimation of chemical reaction kinetics at high-pressure underground coal gasification from the field produced gas composition. This method combines a developed numerical forward model and field data to investigate uncertain parameters. The forward model is developed on the basis of a unique porous media approach that combines the effects of heat, mass transport, and chemical reactions to simulate the underground coal gasification in three-dimensional basis. The chemical reaction kinetics, that is limited to low pressure, is upscaled based on the available experimental data. A comprehensive sensitivity analysis is carried out to estimate the reaction kinetics and investigate the effect of various parameters, such as pressure, temperature, and reaction environment, on the produced gas composition. The novelty of the developed method is in its applicability as well as its ability to generate the chemical reaction kinetics that corresponds to the field under study. The advantage of the proposed technique is that the sensitivity of the model to different kinetic parameters can be investigated by a graphical method.

13/03231 Swarm intelligence and gravitational search algorithm for multi-objective optimization of synthesis gas production

Ganesan, T. *et al. Applied Energy*, 2013, 103, 368–374.

In the chemical industry, the production of methanol, ammonia, hydrogen and higher hydrocarbons require synthesis gas (or syngas). The main three syngas production methods are carbon dioxide reforming (CRM), steam reforming (SRM) and partial-oxidation of methane (POM). In this work, multi-objective (MO) optimization of the combined CRM and POM was carried out. The empirical model and the MO problem formulation for this combined process were obtained from previous works. The central objectives considered in this problem were methane conversion, carbon monoxide selectivity and the hydrogen to carbon monoxide ratio. The MO nature of the problem was tackled using the normal boundary intersection (NBI) method. Two techniques, gravitational search algorithm (GSA) and particle swarm optimization (PSO) were then applied in conjunction with the NBI method. A new local optimum was achieved by using the PSO algorithm in conjunction with the NBI method in this work. Besides, using the PSO and GSA algorithms, the solution spread of the frontier was near-uniform. In terms of uniformity of the spread and computational efficiency, the PSO algorithm was observed to outperform the GSA method.

13/03232 Syngas production from burner-stabilized methane/air flames: the effect of preheated reactants

Smith, C. H. *et al. Combustion and Flame*, 2013, 160, (3), 557–564.

The effect of preheated reactants on syngas production from a methane/air flame was investigated over a range of inlet temperatures up to 630 K. In addition to experimental measurements, the results from a burner-stabilized flame and freely-propagating flame models are presented. A comparison of the modelling and experimental results in terms of flame standoff distance, stability limit conditions and species yields show excellent agreement across a broad range of equivalence ratios and preheat temperatures. Preheating of reactants increased the rich limit for stable operation from 1.26 to 1.75 for a given inlet velocity, and syngas yields were shown to increase with equivalence ratio. The preheat temperature of the reactants was shown to have little impact on syngas yields beyond extending the limits of stable operation. The results of this study are useful for the design and analysis of heat recirculating reactors and other reactors that are designed for producing syngas through the combustion of rich mixtures.

LNG

13/03233 A protocol for the evaluation of LNG vapour dispersion models

Ivings, M. J. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 153–163.

The international transport, storage and utilization of liquefied natural gas (LNG) is growing rapidly. While the LNG industry has an excellent safety record, the possibility of an accidental release cannot be discounted. Internationally accepted standards, such as the 59A standard of the US National Fire Protection Association (NFPA), provide direction on the assessment of LNG spill hazards and hazard range criteria which must be met. Modelling of the atmospheric dispersion of LNG vapour from accidental spills is one of the critical steps in such hazard analyses. This paper describes a comprehensive evaluation protocol devised for the 59A standard, specifically for the assessment of LNG vapour dispersion models. The evaluation protocol is based on methodologies developed in previous European Union studies, which have been extended, significantly adapted and tailored to the specific requirements of the evaluation of models for the dispersion of LNG vapour. The protocol comprises scientific evaluation of the numerical and physical basis of models for the dispersion of LNG vapour, model verification, and validation; resulting in a comprehensive model evaluation report which includes qualitative and quantitative criteria for model acceptance. A supporting suite of validation data, and guidance on the use of this data, has also been produced. The NFPA 59A (2009) standard states that LNG vapour dispersion models are acceptable for use if they have been evaluated in accordance with this protocol.

13/03234 Application of inverse methods based algorithms to liquefied natural gas (LNG) storage management

Lukaszewski, M. W. *et al. Chemical Engineering Research and Design*, 2013, 91, (3), 457–463.

Liquefied natural gas (LNG) is one of the major fossil fuels used throughout the world and is to gain even more of the market share being the cleanest burning fossil fuel and also due to its availability. In addition, now it becomes crucial to improve the existing LNG storage models to support safe and economic managing of LNG storage sites. In this article two inverse methods are compared. First one, being the previously developed optimization method for the real-time inverse problem, is analysed and its main characteristics are identified. Next, an alternative method is being proposed, based on normal equations applied to non-linear parameter estimation, dealing with the main limitations of the previous approach. Both methods significantly improve the accuracy of LNG storage models and credibility of predictions, by making use of the available measurements from the tank's gauges and processing them with the developed algorithms.

13/03235 Computational fluid dynamics analysis of liquefied natural gas dispersion for risk assessment strategies

Sun, B. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 117–128.

Computational fluid dynamics (CFD) simulations have been conducted for dense gas dispersion of liquefied natural gas (LNG). The simulations have taken into account the effects of gravity, time-dependent downwind and crosswind dispersion, and terrain. Experimental data from the Burro series field tests, and results from integral model (DEGADIS) have been used to assess the validity of simulation results, which were found to compare better with experimental data than the commonly used integral model DEGADIS. The average relative error in maximum downwind gas concentration between CFD predictions and experimental data was 19.62%. The validated CFD model was then used to perform risk assessment for most-likely-spill scenario at LNG stations as described in the standard of NFPA 59A (2009) 'Standard for the Production, Storage and Handling of Liquefied Natural Gas'. Simulations were conducted to calculate the gas dispersion behaviour in the presence of obstacles (dyke walls). Interestingly for spill at a higher elevation, e.g. tank top, the effect of impounding dikes on the affected area was minimal. However, the impoundment zone did affect the wind velocity field in general, and generated a swirl inside it, which then played an important function in confining the dispersion cloud inside the dyke. For most cases, almost 75% of the dispersed vapour was retained inside the impoundment zone. The finding and analysis presented here will provide an important tool for designing LNG plant layout and site selection.

Hydrogen generation and storage

13/03236 Catalytic hydrothermal gasification of algae for hydrogen production: composition of reaction products and potential for nutrient recycling

Onwudili, J. A. *et al. Bioresource Technology*, 2013, 127, 72–80.

Chlorella vulgaris, *Spirulina platensis* and *Saccharina latissima* were processed under supercritical water gasification conditions at 500 °C, 36 MPa in an Inconel batch reactor for 30 min in the presence/absence of NaOH and/or Ni–Al_2O_3. Hydrogen gas yields were more than two times higher in the presence of NaOH than in its absence and tar yields were reduced by up to 71%. *Saccharina*, a carbohydrate-rich macro-alga, gave the highest hydrogen gas yields of 15.1 mol/kg. The tars from all three algae contained aromatic compounds, including phenols, alkyl benzenes and polycyclic aromatic hydrocarbons as well as heterocyclic nitrogen compounds. Tars from *Chlorella* and *Spirulina* contained high yields of pyridines, pyrroles, indoles and pyrimidines. Up to 97% TOC removal were achieved in the process waters from the gasification of the algae. Analyses for specific nutrients in the process waters indicated that the process waters from *Saccharina* could potentially be used for microalgae cultivation.

13/03237 Electrochemical oxidation and microfiltration of municipal wastewater with simultaneous hydrogen production: influence of organic and particulate matter

Park, H. *et al. Chemical Engineering Journal*, 2013, 215–216, 802–810.

Electrochemical reactions, which can produce molecular hydrogen via water splitting, can degrade organic contaminants in water simultaneously. This study focused on the production of hydrogen gas during the electrochemical treatment of organic matter and colloids present in actual municipal wastewater. The electrochemical system used in this study consisted of a BiO_x–TiO_2/Ti anode and two stainless steel cathodes. Hydrogen generation was enhanced in the presence of wastewater organic matter and/or supplemental NaCl. During the electrochemical reaction, the chemical oxygen demand, proteins, and turbidity were removed well, whereas the dissolved organic carbon, carbohydrates, and organic acids concentrations remained unchanged or rather increased. The increase in dissolved carbon content was ascribed to the conversion of particulate colloids to soluble fractions and thereafter incomplete mineralization. Both the loss of organic fluorophores and the formation of large molecular organics during electrochemical oxidation exhibited the degradation of primarily present organics as well as the solubilization of particulate colloids. The accumulation and formation of oxalate and chlorinated intermediates, such as trichloromethane, also occurred. The wastewater particles larger than 0.1 μm in size were responsible for the formation of dissolved organic intermediates, but such colloidal particles seemed beneficial to hydrogen generation. Microfiltration in conjunction with electrochemical treatment showed the potential to produce good quality effluent at a high permeability while simultaneously generating hydrogen energy.

13/03238 Electrolysis of urea and urine for solar hydrogen

Kim, J. *et al. Catalysis Today*, 2013, 199, 2–7.

Hybrid photovoltaic (PV) arrays-electrochemical systems have been envisaged as an alternative technology that co-manages an energy–water nexus, yet improving the technical viability and applicability of the hybrids remains a challenge. With this in mind, the authors studied the hybrid electrochemical system for urea and urine treatment and simultaneous H_2 production using BiO_x–TiO_2 anode and stainless steel cathode couples with different electrolytes (NaCl vs. $LiClO_4$ vs. Na_2SO_4). In the presence of NaCl, urea electrolysis was found to enhance the cathodic H_2 production by a maximum of *ca.* 20% at low urea concentrations, yet reduce the H_2 production at high urea concentrations as compared to water electrolysis. Varying degrees of the synergistic H_2 production were attributed to competitive reactions between active chlorine species and urea/urea intermediates for protons and electrons. The synergistic effect by the urea electrolysis disappeared when $LiClO_4$ and Na_2SO_4 were used as electrolytes indicating the crucial role of chlorine species in the hybrid reactions. In addition, the electrolysis of actual urine was found to successfully operate along with simultaneous generation of H_2 even in the absence of externally added electrolytes. This electrolyteless-hybrid electrolysis resulted from the large amounts of chloride and other ionic species originally included in the actual urine sample. A detailed reaction mechanism of urea electrolysis and its application potential in terms of solar hydrogen were discussed.

13/03239 Enhanced photocatalytic hydrogen generation with Pt Nanoparticles on multi-phase polycrystalline microporous MnO_2 photocatalyst

Pai, Y.-H. *et al. Journal of Power Sources*, 2013, 223, 107–113.

A multi-phase polycrystalline microporous manganese dioxide (MnO_2) photocatalyst for light-induced water splitting and hydrogen generation is performed via a redox reaction under various hydrothermal conditions. By tuning the precursor concentrations down to 0.1 M, two kinds of Mn–O functional groups, including pyrolusite structures at 416, 433, 455, 609 and 646 cm^{-1} and ramsdellite structures at 466 and 576 cm^{-1}, can be obtained by FT-IR. Morphological and phase characterizations are also examined by FE-SEM and XRD techniques, respectively. A series of peaks, corresponding to planes (110) and (200) of the sample can be indexed as a β-MnO_2 crystal with a corresponding lattice spacing of 3.11 and 2.19 Å. In particular, a significant enhancement of light-induced hydrogen generation by water splitting has been observed at a Pt–MnO_2/C photocatalyst with an optimum hydrogen generation rate of 2261 $\mu mol\,g^{-1}\,h^{-1}$ due to the improvement of electro-oxidation of methanol aqueous solutions, compared to a Pt–TiO_2/C photocatalyst. The photoelectrochemical measurement also indicates that the multi-phase polycrystalline macroporous MnO_2 photocatalyst can indeed effectively inhibit CO poisoning, help CO re-oxidation in the cocatalyst surface and maintain the catalyst's surface area in methanol oxidation and hydrogen generation efficiency.

13/03240 Experimental determination of dust cloud deflagration parameters of selected hydrogen storage materials: complex metal hydrides, chemical hydrides, and adsorbents

Khalil, Y. F. *Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 96–103.

This paper discusses the results of an experimental program carried out to determine dust cloud deflagration parameters of selected solid-state hydrogen storage materials, including complex metal hydrides (sodium alanate and lithium borohydride/magnesium hydride mixture), chemical hydrides (alane and ammonia borane) and activated carbon (Maxsorb, AX-21). The measured parameters include maximum deflagration pressure rise, maximum rate of pressure rise, minimum ignition temperature, minimum ignition energy and minimum explosive concentration. The calculated explosion indexes include volume-normalized maximum rate of pressure rise (K_{St}), explosion severity (*ES*) and ignition sensitivity (*IS*). The deflagration parameters of Pittsburgh seam coal dust and Lycopodium spores (reference materials) are also measured. The results show that activated carbon is the safest hydrogen storage media among the examined materials. Ammonia borane is unsafe to use because of the high explosivity of its dust. The core insights of this contribution are useful for quantifying the risks associated with use of these materials for on-board systems in light-duty fuel cell-powered vehicles and for supporting the development of hydrogen safety codes and standards. These insights are also critical for designing adequate safety features such as explosion relief venting and isolation devices and for supplementing missing data in materials safety data sheets.

13/03241 Experimental study on the hydrogen charge and discharge rates of metal hydride tanks using heat pipes to enhance heat transfer

Chung, C. A. *et al. Applied Energy*, 2013, 103, 581–587.

Heat transfer is a critical factor affecting the performance of metal hydrogen storage tanks. Many studies have proposed inner tubular heat exchangers for increasing the heat transfer rate between the metal powders and the exterior environment of the tanks. However, connecting cooling and heating fluid tubes to the storage tanks can be a tedious task, especially for large-scale hydrogen storage systems with a large array of tanks. This study presents a novel design for a metal hydride vessel equipped with heat pipes. These heat pipes enhance heat transfer for hydrogen charge and discharge without the need for tubing through the metal bed. This study experimentally demonstrates the effects of using heat pipes to enhance heat transfer in a hydrogen storage tank using $LaNi_5$ as the storage media and comparing tanks with and without heat pipes. Results show that heat pipes can enhance the hydrogen storage rates in both absorption and desorption. The absorption time was reduced more than half with a 10 atm hydrogen supply pressure, and the desorption time for hydrogen discharge at 1 L/min was increased by 44%.

13/03242 Heliostat-field gain-scheduling control applied to a two-step solar hydrogen production plant

Roca, L. *et al. Applied Energy*, 2013, 103, 298–305.

This paper describes a temperature control structure designed for the interior of a solar hydrogen reactor based on a two-step ferrite-redox technology. Until now, this temperature has been controlled by manual selection of the heliostats to be focused on the receiver targets. However, the strong system dependency on operating conditions suggests that the procedure be automated in order to ensure the desired setpoint change response. The aims are to maintain the desired temperatures and to make the setpoint switch as fast as possible, keeping plant conditions within the margins of safety. The scheme proposed includes a procedure for selecting the heliostats to be focused on the reactor by using a simple model of the solar field and a gain scheduling control system which changes the control tuning parameters to deal with the varying dynamics observed during the process. Real experiments show the promising results of this work.

13/03243 High yield single stage conversion of glucose to hydrogen by photofermentation with continuous cultures of *Rhodobacter capsulatus* JP91

Abo-Hashesh, M. *et al. Bioresource Technology*, 2013, 128, 513–517.

Photofermentative hydrogen (H_2) production from glucose with the photosynthetic bacterium *Rhodobacter capsulatus* JP91 (hup^-) was examined using a photobioreactor operated in continuous mode. Stable and high hydrogen yields on glucose were obtained at three different retention times (HRTs; 24, 48 and 72 h). The H_2 production rates, varying between 0.57 and 0.81 mmol/h, and optical densities (OD_{600nm}) were similar for the different HRTs examined. However, the rate of glucose consumption was influenced by HRT being greater at HRT 24 h than HRTs 48 and 72 h. The highest hydrogen yield, 9.0 ± 1.2 mol H_2/mol glucose, was obtained at 48 h HRT. These results show that single stage photofermentative hydrogen production from glucose using photobioreactors operated in continuous culture mode gives high, nearly stoichiometric yields of hydrogen from glucose, and thus is considerably more promising than either two stage photofermentation or co-culture approaches.

13/03244 Hydrogen production from oxidative steam reforming of bio-butanol over CoIr-based catalysts: effect of the support

Cai, W. *et al. Bioresource Technology*, 2013, 128, 467–471.

This paper studies the influence of the support on the behaviour of bimetallic CoIr-based catalysts (6.5 wt% Co, 0.4 wt% Ir) for hydrogen production from the oxidative steam reforming of bio-butanol raw mixture (butanol/acetone/ethanol = 6/3/1 mass ratio). Catalytic tests were carried out at 500 °C for 60 h with raw mixture/water/air/Ar = 1/10/7.5/12 molar ratio and GHSV = 7500 h^{-1}. Over CoIr/18CeZrO_2 and CoIr/ZnO the main process which took place was the oxidative steam reforming of the raw mixture. CoIr/18CeZrO_2 showed the better catalytic performance. Characterization of the used catalysts indicated that both active metal sintering and coke formation was prevented on the CoIr/18CeZrO_2 catalyst.

13/03245 *In silico* evaluation of a complex multi-enzymatic system using one-pot and modular approaches: application to the high-yield production of hydrogen from a synthetic metabolic pathway

Ardao, I. and Zeng, A.-P. *Chemical Engineering Science*, 2013, 87, 183–193.

Multi-enzymatic processes are becoming increasingly attractive for the production of chemicals and pharmaceuticals at an industrial level due to a drastic reduction on the down-stream steps that leads to a better exploitation of resources. One-pot processes (all the enzymes placed in the same reactor) are the most commonly used approach although they present a number of limitations. This work explores the use of modular processes (enzymes distributed in different reactors) as an alternative to overcome the limitations of one-pot processes. An *in silico* evaluation of different process alternatives was performed, taking as an example a multi-enzymatic system for high-yield production of hydrogen from biomass catalysed by a synthetic metabolic pathway composed of 13 enzymes. A modular process where an hyperthermophilic hydrogenase is kept at higher temperature than the rest of the enzymes lead to a two-fold increase in productivity, whereas a separate reactor that consumes an inhibitor of other enzymes lead to an eight-fold increase in productivity, compared to the one-pot operation. A multi-objective optimization of the one-pot process for the maximization of productivity and yield was also performed using a genetic algorithm. Productivities of up to 355 mmol/L/h was expected to be achieved without compromising the high yield of the process (11.3 mol of H_2 produced per mol substrate) under the conditions studied.

13/03246 Increased H_2 gravimetric storage capacity in truncated carbon slit pores modeled by grand canonical Monte Carlo

Firlej, L. *et al. Carbon*, 2013, 53, 208–215.

Hydrogen adsorption in slit shaped pores built up from truncated graphene fragments has been simulated using the grand canonical Monte Carlo technique and the influence of pore wall edges on hydrogen storage by physisorption has been analysed. The authors show that due to the additional gas adsorption at the pore edges the adsorbed gravimetric amount significantly increases (by a factor of two) with respect to models of pores with infinite graphene walls. The contribution of the edges' adsorption to the total hydrogen uptake is independent of the pore wall shape but it depends on its surface. They also show that the maximum of the excess adsorption shifts towards higher pressures when the edge contribution increases. This information can be used to characterize experimentally structures of porous adsorbents and complement pore size distribution analysis usually performed with gases others than hydrogen. It is suggested that porous carbons built from polycyclic hydrocarbons can achieve storage performances required for practical applications.

13/03247 Integration of first and second generation biofuels: fermentative hydrogen production from wheat grain and straw

Panagiotopoulos, I. A. *et al. Bioresource Technology*, 2013, 128, 345–350.

Integrating of lignocellulose-based and starch-rich biomass-based hydrogen production was investigated by mixing wheat straw hydrolysate with a wheat grain hydrolysate for improved fermentation. Enzymatic pretreatment and hydrolysis of wheat grains led to a hydrolysate with a sugar concentration of 93.4 g/L, while dilute-acid pretreatment and enzymatic hydrolysis of wheat straw led to a hydrolysate with sugar concentration 23.0 g/L. Wheat grain hydrolysate was not suitable for hydrogen production by the extreme thermophilic bacterium *Caldicellulosiruptor saccharolyticus* at glucose concentrations of 10 g/L or higher, and wheat straw hydrolysate showed good fermentability at total sugar concentrations of up to 10 g/L. The mixed hydrolysates showed good fermentability at the highest tested sugar concentration of 20 g/L, with a hydrogen production of 82–97% of that of the control with pure sugars. Mixing wheat grain hydrolysate with wheat straw hydrolysate would be beneficial for fermentative hydrogen production in a biorefinery.

13/03248 Photocatalytic generation of hydrogen with visible-light nitrogen-doped lanthanum titanium oxides

Meng, F. *et al. Catalysis Today*, 2013, 199, 48–52.

In order to generate hydrogen by splitting water under visible-light irradiation, nitrogen-doped $La_2Ti_2O_7$ (LTO) nanosheets loaded with the Pt nanoparticles have been synthesized by hydrothermal processing, followed with wet impregnation and subsequent heat treatment in a NH_3 flow. The light absorption of the pristine LTO nanosheets is cut off at 330 nm while the N-doped LTO nanosheets exhibit the extended light absorption up to 560 nm. Nitrogen doping has not only resulted in the visible-light-responsive photocatalytic water splitting but also enhanced the ultraviolet-light-responsive photocatalytic activity. Loading the Pt nanoparticles on the LTO surface further improved the photocatalytic activity due to the enhanced separation of charge carriers.

13/03249 Pyrolysis/gasification of cellulose, hemicellulose and lignin for hydrogen production in the presence of various nickel-based catalysts

Wu, C. *et al. Fuel*, 2013, 106, 697–706.

Cellulose, hemicellulose and lignin are the main components of biomass. This work presents research into the pyrolysis/gasification of all three main components of biomass, in order to evaluate and compare their hydrogen production and also understand their gasification processes. A fixed bed, two-stage reaction system has been used employing various nickel-based catalysts. Gas concentration (CO, H_2, CO, CO_2 and CH_4) was analysed for the produced non-condensed gases. Oil by-products were analysed by gas chromatography/mass spectrometry (GC/MS). Various techniques such as X-Ray diffraction, scanning electron microscopy coupled to an energy dispersive X-ray spectroscopy, temperature-programmed oxidation were applied to characterize the fresh or reacted catalysts. The experimental results show that the lignin sample generates the highest residue fraction (52.0 wt%) among the three biomass components. When Ni–Zn–Al (1:1) catalyst was used in the gasification process, gas yield was increased from 62.4 to 68.2 wt% for cellulose, and from 25.2 to 50.0 wt% for the pyrolysis/gasification of lignin. Hydrogen production was increased from 7.0 to 18.7 (m mol g^{-1} sample) when the Ni–Zn–Al (1:1) catalyst was introduced in the pyrolysis/gasification of cellulose. Among the investigated catalysts, Ni–Ca–Al (1:1) was found to be the most effective for hydrogen production from cellulose pyrolysis/gasification.

13/03250 Thermodynamic analysis of hydrogen production by steam and autothermal reforming of soybean waste frying oil

Noureddine, H. *et al. Energy Conversion and Management*, 2013, 70, 174–186.

Hydrogen production via steam and autothermal reforming of soybean waste frying oils (WFOs) is thermodynamically investigated via the Gibbs free energy minimization method. The thermodynamic optimum conditions are determined to maximize hydrogen production while minimizing the methane and carbon monoxide contents and coke formation. Equilibrium calculations are performed at atmospheric pressure over a wide range of temperatures (400–1200 °C), steam-to-WFO ratios (*S*/*C*: 1–15) and oxygen-to-WFO ratios (*O*/*C*: 0.0–2.0). The baseline case used for the study considers soybean WFO after 8 h of use (WFO8). The influence of frying time on the performance of reforming reactors is also discussed. The results show that the optimum conditions for steam reforming can be achieved at reforming temperatures between 650 and 850 °C and at a steam to carbon molar (*S*/*C*) ratio of approximately 5. The recommended operation conditions for the SR of WFO8 are proposed to be T = 650 °C and *S*/*C* ratio = 5. Under these conditions, a hydrogen yield of 169.83 mol/kg WFO8 can be obtained with a CO concentration in the SG of 3.91% and trace CH_4 (0.03%), without the risk of coke formation. Hydrogen production from autothermal systems can be optimized at temperatures of 600–800 °C, *S*/*C* ratios of 3–5, and *O*/*C* ratios of 0.0–0.5. Under these conditions, thermoneutrality is obtained with *O*/*C* ratios of 0.391–0.455. The recommended thermoneutral conditions are $S/C = 5$, T = 600 °C and $O/C = 0.453$. Under these conditions, 146.45 mol H_2/kg WFO8 can be produced with only 2.89% CO and 0.06% CH_4 in the synthesis gas. The effect of frying time of soybean WFO on hydrogen productivity is shown to be negligible.

04 BY-PRODUCTS RELATED TO FUELS

13/03251 A combined process of activated carbon adsorption, ion exchange resin treatment and membrane concentration for recovery of dissolved organics in pre-hydrolysis liquor of the kraft-based dissolving pulp production process

Shen, J. *et al. Bioresource Technology*, 2013, 127, 59–65.

To recover dissolved organics in pre-hydrolysis liquor (PHL) of the kraft-based dissolving pulp production process, a new combined process concept of sequential steps of activated carbon adsorption, ion exchange resin treatment, and membrane concentration, was proposed. The removal of lignin in the PHL was achieved in the activated carbon adsorption step, which also facilitates the subsequent operations, such as the membrane filtration and ion exchange resin treatment. The ion exchange resin treatment resulted in the removal/concentration of acetic acid, which opens the door for acetic acid recovery. The membrane filtration is to recover/concentrate the dissolved sugars. The combined process resulted in the production of PHL-based concentrate with relatively high concentration of hemicellulosic sugars, i.e. 22.13%.

13/03252 Electrochemical properties of Pt/graphene intercalated by carbon black and its application in polymer electrolyte membrane fuel cell

Cho, S. H. *et al. Journal of Power Sources*, 2013, 225, 200–206.

Graphene single nanosheet (GNS) is synthesized from graphite by chemical oxidation and thermal exfoliation at 1000 °C and confirmed by X-ray diffraction analysis. Scanning electron and transmission electron microscope images clearly show the lateral expansion of graphite sheet and uniform dispersion of Pt nanoparticles on GNS. Fourier transform infrared and X-ray photoelectron spectroscopy analyses are conducted for surface properties of GNS such as oxygenated functional groups. Cyclic voltammetric analysis shows that electrochemical active surface areas (ECSAs) for Pt/GNS, commercial Pt/Vulcan XC-72 carbon black and Pt-incorporated onto commercial carbon black (Pt/CB) prepared in the laboratory are 33.1, 23.5 and 22.5 $m^2 g^{-1}$, respectively. Because of significant restacking of Pt/GNS sheets, carbon black (CB) with different content is intercalated between Pt/GNS as a spacer. The ECSAs of Pt/GNS, Pt/GNS/CB20, Pt/GNS/CB30 and Pt/GNS/CB40 are evaluated to be 31.5, 28.6, 38.8 and 30.4 $m^2 g^{-1}$, respectively. The cell performance highly depends on CB content and Pt/GNS/CB with 30 wt% of CB content shows the best cell performance of 400 mA cm^{-2}.

13/03253 Investigation of the potential of coal combustion fly ash for mineral sequestration of CO_2 by accelerated carbonation

Ukwattage, N. L. *et al. Energy*, 2013, 52, 230–236.

Mineral carbonation of alkaline waste materials is being studied extensively for its potential as a way of reducing the increased level of CO_2 in the atmosphere. Carbonation converts CO_2 into minerals which are stable over geological time scales. This process occurs naturally but slowly, and needs to be accelerated to offset the present rate of emissions from power plants and other emission sources. The present study attempts to identify the potential of coal fly ash as a source for carbon storage (sequestration) through *ex situ* accelerated mineral carbonation. In the study, two operational parameters that could affect the reaction process were tested to investigate their effect on mineralization. Coal fly ash was mixed with water to different water-to-solid ratios and samples were carbonated in a pressure vessel at different initial CO_2 pressures. Temperature was kept constant at 40 °C. According to the results, one ton of Hazelwood fly ash could sequester 7.66 kg of CO_2. The pressure of CO_2 inside the vessel has an effect on the rate of CO_2 uptake and the water-to-solid ratio affects the weight gain after the carbonation of fly ash. The results confirm the possibility of the manipulation of process parameters in enhancing the carbonation reaction.

13/03254 Novel Fe loaded activated carbons with tailored properties for As(V) removal: adsorption study correlated with carbon surface chemistry

Lodeiro, P. *et al. Chemical Engineering Journal*, 2013, 215–216, 105–112.

Novel Fe loaded activated carbons have been prepared from sugar beet pulp (BP) agricultural residues by direct steam activation followed by iron impregnation with or without previous oxidation. The corresponding activated carbons were: BP–H_2O, BP–H_2O–Fe, BP–H_2O–H_2O_2–Fe and BP–H_2O–MnO_2–Fe. The textural characterization of these tailored activated carbons was based on nitrogen adsorption/desorption isotherms leading to BET surface area values between 741 and 821 m^2/g and total porous volumes between 0.58 and 0.79 cm^3/g. Elemental analysis and ash content showed that carbon content reached 78% for BP–H_2O with 13.6% of ash and decreased to 50% in iron-based materials. BP–H_2O and BP–H_2O–Fe revealed a basic nature with pH_{PZC} values of 9.8 and 9 respectively while BP–H_2O–H_2O_2–Fe and BP–H_2O–MnO_2–Fe had acid pH_{PZC} (5.1 and 3.6). Their surface chemistry has been investigated by XPS analysis and by the quantification of the surface chemical moieties based on Boehm's approach. A clear relationship was found between the surface iron content and the strong acidic groups. Arsenic (As(V)) adsorption isotherms were performed and Langmuir, Freundlich, Redlich–Peterson models were used to describe the experimental data by non-linear regression. It was found that Redlich–Peterson isotherm provided the best fit and the Langmuir adsorption capacities confirmed that the iron-based activated carbons were highly attractive for As(V) removal with capacities up to 17 mg g^{-1}. Finally, it has been shown that the surface iron content determined by XPS analysis is very well correlated with Langmuir q_m values ($r^2 = 0.982$) and with the strong acidic moieties deduced from the Boehm's method.

13/03255 Optimization of mineral carbonation process for CO_2 sequestration by lime-rich coal ashes

Mayoral, M. C. *et al. Fuel*, 2013, 106, 448–454.

Mineral carbonation is one of the alternatives considered for CO_2 sequestration. This consists of inducing the artificial weathering of alkaline minerals to produce stable carbonate solids. This work presents the wet carbonation of lime-rich ashes from the fluidized bed combustion of two different fuels: a Spanish sulfur-rich lignite, with calcium carbonate and quartz as main mineral constituents, and the waste produced during the extraction of the coal. The novelty of the work is its experimental approach, which explores all the variables (pH, temperature, time, liquid to solid ratio, NaCl ratio) from a statistical survey centred on finding optimized conditions that maximize the degree of carbonation. CO_2 uptake is determined by direct thermogravimetric tests. The results indicate that high carbonation efficiency (78% efficiency) is achieved for both solids at basic pH and moderate treatment times. Those conditions cause anhydrite to dissolve, increasing the availability of Ca^{2+} for reprecipitation as carbonate and hydroxide. At neutral pH, 72% conversion efficiency is equivalent to a capture of 8% of the CO_2 theoretically emitted in the combustion of coal wastes. The proposed conditions for fly ash carbonation enables rapid CO_2 capture that is applicable for upscaling and industrial use.

13/03256 Quantitative Rietveld analysis of the crystalline and amorphous phases in coal fly ashes

Ibáñez, J. *et al. Fuel*, 2013, 105, 314–317.

X-ray powder diffraction (XRD) in combination with the Rietveld method was used to evaluate the proportion of crystalline and amorphous (glassy) phases in fly ashes produced in pulverized-coal-combustion (PCC) power plants. The quantification of amorphous phases through the Rietveld method is most usually carried out (i) by using an internal standard or (ii) by using a poorly-crystalline phase to represent the amorphous phase in the lineshape calculations. This study explores the usefulness of an alternative method that relies on the calibration of the broad XRD signal arising from the amorphous phase. This procedure, which does not require any spiking of the samples, provides a suitable alternative to evaluate in an easy, fast and consistent manner the amount of crystalline and amorphous phases in the fly ashes.

13/03257 Relationship between coal ash composition and ash fusion temperatures

Liu, B. *et al. Fuel*, 2013, 105, 293–300.

Coal ash fusion characterization and the ash fusion temperatures (AFTs) are important parameters for coal industry. Previous research has proved that the AFTs are correlated with the chemical composition of coal ash samples. In this paper, a five-component SiO_2–Al_2O_3–CaO–Fe_2O_3–K_2O system is set. The AFTs of 34 synthetic ashes were measured in a carbon atmosphere, and the trends of the AFTs analysed. Different from other studies, X-ray diffraction and scanning electron microscope were combined to explore the relationships between the measured AFTs and the mineral composition, morphology and microstructure of ash samples. Furthermore, the effect of the element valence state is also taken into account and X-ray photoelectron spectrometer is used to analyse it at first. The results show that the AFTs decrease with the increasing Fe_2O_3 content and silica-to-alumina (S/A) ratio. However, for the effect of CaO content, the AFTs reach a minimum value and then increase once again. Furthermore, the AFTs show no significant change as the K_2O content varies. At last, all the conclusions found from the synthetic samples are also applicable for the 17 bituminous coal ashes collected locally and abroad.

13/03258 Seasonal variation in the spatial distribution of aerosol black carbon over Bay of Bengal: a synthesis of multi-campaign measurements

Kompalli, S. K. *et al. Atmospheric Environment*, 2013, 64, 366–373.

Synthesizing data from several cruise experiments over the Bay of Bengal (BoB), the seasonal characterization of aerosol black carbon (BC) mass concentration was made. The study indicated that the BC mass concentration (M_{BC}) showed significant seasonal variation over the oceanic region with M_{BC} being the highest during the winter season ($\sim 2407 \pm 1756$ ng m^{-3}) and lowest in summer monsoon ($\sim 765 \pm 235$ ng m^{-3}). The seasonal changes in the BC mass concentration were more prominent over the northern BoB (having an annual amplitude of ~4) compared to southern BoB (amplitude ~ 2). Significant spatial gradients in M_{BC}, latitudinal as well as longitudinal, existed in all the seasons. Latitudinal gradients, despite being consistently increasing northwards, were found to be sharper during winter and weakest during summer monsoon with e-fold scaling distances of ~7.7° and ~15.6° during winter and summer monsoon seasons respectively. Longitudinally, BC concentrations tend to increase toward east during winter and pre-monsoon seasons, but an opposite trend was seen in monsoon season highlighting the seasonally changing source impacts on BC loading over BoB. Examination of the results in light of possible role of transport from adjoining landmasses, using air mass back trajectory cluster analysis, also supported spatially and temporally varying source influence on oceanic region.

05 NUCLEAR FUELS

Scientific, technical

13/03259 A numerical study of flow and mixing characteristics inside the chimney structure of a pool type research reactor

Sengupta, S. *et al. Annals of Nuclear Energy*, 2013, 51, 167–180.

Numerical studies were performed to examine the effects of flow velocities of opposing streams on the flow pattern and turbulent mixing characteristics in a three-dimensional chimney structure using the computational fluid dynamics code PHOENICS. This chimney structure facilitates guiding of the radioactive water from the reactor core (i.e. core flow) towards the side outlet nozzles and simultaneously drawing out water from the reactor pool through the chimney top. The radioactive water flows upward and has a tendency to reach to the pool top through the chimney top, which is open for fuel and isotope handling. The chimney design allows drawing out a part of the pool water in the downward direction to suppress the upward flowing radioactive water jet. This downward flow through the chimney is compensated by providing additional core bypass flow to the pool. Analyses were carried out on 1:1 chimney structure and also on sixth scaled down chimney model to understand the similarity of behaviour of the model and the prototype. Mass flow rate of upward flowing water (i.e. core flow) is considered to be 750 kg/s and core bypass flow is varied from 0% to 15% that of the core flow. In the model study, mass flow rate was varied from 8.33 to 25 kg/s and core bypass flow was considered to vary from 0% to 15%. Flow mixing pattern inside the chimney and the non-dimensional stagnation depth was predicted for the model and the prototype. It was observed that there is a good similarity in behaviour of the prototype and model.

13/03260 A preliminary study of target multiplicity for ADSRs

Ahmad, A. *et al. Energy Conversion and Management*, 2013, 69, 181–190.

The accelerator-driven subcritical reactor (ADSR) concept is based on the coupling of a particle accelerator to a subcritical reactor core by means of a neutron spallation target interface. This paper investigates the benefits of multiple spallation targets in ADSRs. The motivation behind this is, first, to improve the overall reliability of the accelerator–reactor system, and, second, to evaluate other potential advantages such as lower beam power requirements. The results show that a system containing two or three spallation targets, coupled to independent accelerators, offers better neutronic performance. This is demonstrated through the increased effective multiplication factor (k_{eff}) in the two- and three-target configurations and a more uniform neutron flux distribution. A multiple-target ADSR also proves to be effective in mitigating the impact of frequent beam interruptions, a pressing issue that needs to be addressed for the ADSR concept to advance. Assuming no simultaneous beam shutdowns, the two- and three-target configurations reduce the risk of fuel cladding failure due to thermal cyclic fatigue.

13/03261 An analytical solution for thermal–hydraulic analysis and safety margins in MTR-type research reactors cooled by natural convection

Ardaneh, K. and Zaferanlouei, S. *Annals of Nuclear Energy*, 2013, 51, 282–288.

An analytical solution has been developed to analyse the thermal–hydraulic behaviour of MTR research reactors under steady-state natural convection. The approach is based on the one-dimensional conservation equations of mass, energy, momentum, and Boussinesq approximation as the equation of state. SILOE Research Reactor and Tehran Research Reactor (TRR) are taken as the benchmark problems. For all ranges of power under single phase natural convection, the relative difference between analytical predictions and experimental measurements lies in the range 0.01–7.0%. Also, the results are compared with the corresponding results obtained with CONVEC V3.40 computer code. Having achieved a good agreement shows the analytical solution is practicable to predict safety margins for MTR-type research reactors under natural convection. The safe operating power levels for TRR and the safety margins against onset of nucleate boiling, pulsed boiling, and burnout are evaluated with this analytical solution.

13/03262 Characterization of a gas elliptic jet in a nuclear safety scenario

Herranz, L. E. and Velasco, F. J. S. *Experimental Thermal and Fluid Science*, 2013, 44, 374–384.

This paper summarizes the major insights gained into the aerodynamics of a subsonic gas jet expanding across a bundle of tubes from an axial-type tube breach. This scenario is highly relevant in nuclear safety since it determines the potential retention of radioactive aerosol particles during a severe accident steam generator tube rupture (SGTR) sequence. A scaled-down mock-up with representative dimensions of a real shell and tube heat exchanger of a nuclear power plant was used in the experiments. Two-dimensional (2D) PIV technique was used to characterize the flow field in the space between the breach and the neighbour tubes in the Reynolds range investigated ($\mathrm{Re}_D = 0.8$–2.7×10^5). The free jet case (i.e. jet expansion in a 'tube-free' space) was used as a reference to compare the 'in-bundle' jet case. By comparing with previous results obtained with an axisymmetric radial tube breach, the effect of the type of breach in the nearby flow field across the bundle has been also analysed. Results show that an axial tube breach generates an elliptic jet with 'quasi top-hat' velocity profile. The presence of tubes distorts the jet shape, reduce its penetration and its gas entrainment with respect to a 'tube-free' space. The type of breach drastically affects the jet evolution in the surroundings of the breach. Particularly, different velocity profiles and jet flow entrainments have been found for the same upstream conditions. Results are being applied in the development of aerosol retention models of severe accident SGTR sequences.

13/03263 Comparative study of transient thermal–hydraulic characteristics of SCWRs with different core design

Zhu, D. *et al. Annals of Nuclear Energy*, 2013, 51, 135–145.

The comparative studies of transient flow characteristics and the consequent safety performance for supercritical water reactors (SCWRs) with different flow path designs have been performed. Three different SCWR concepts, SCWR-M, American SCWR and SSCWR, are, respectively, selected as the representations of multi-pass core, one-pass core with water rods and one-pass core without water rods. The comparative analyses of loss of flow accident (LOFA) are carried out for the three SCWR concepts by TACOS code. The flow rate and cladding temperature behaviours are compared to each other. The results show that the SCWR-M and the American SCWR concepts have more complicated transient flow characteristics than the SSCWR. Under the assumed condition in the work, inverse flow occurs both in the SCWR-M and the American SCWR following the LOFA. The evaluation of the effect of AFS flow rate indicates that the flow path design of the SCWR-M would require larger injection flow rate than the other two concepts to mitigate the LOFA.

13/03264 Corrosion study of a highly durable electrolyzer based on cold crucible technique for pyrochemical reprocessing of spent nuclear oxide fuel

Takeuchi, M. *et al. Journal of Nuclear Materials*, 2013, 432, (1–3), 35–41.

The application of the cold crucible technique to a pyrochemical electrolyser used in the oxide-electrowinning method, which is a method for the pyrochemical reprocessing of spent nuclear oxide fuel, is proposed as a means for improving corrosion resistance. The electrolyser suffers from a severe corrosion environment consisting of molten salt and corrosive gas. In this study, corrosion tests for several metals in molten 2CsCl–NaCl at 923 K with purging chlorine gas were conducted under controlled material temperature conditions. The results revealed that the corrosion rates of several materials were significantly decreased by the material cooling effect. In particular, Hastelloy C-22 showed excellent corrosion resistance with a corrosion rate of just under 0.01 mm/y in both molten salt and vapour phases by controlling the material surface at 473 K. Finally, an engineering-scale crucible composed of Hastelloy C-22 was manufactured to demonstrate the basic function of the cold crucible. The cold crucible induction melting system with the new concept Hastelloy crucible showed good compatibility with respect to its heating and cooling performances.

13/03265 Effect of radial zoning of ^{241}Am content on homogenization of denatured Pu with broad range of neutron energy based on U irradiation test in the experimental fast reactor Joyo

Shiba, T. *et al. Annals of Nuclear Energy*, 2013, 51, 74–80.

The design consideration of depleted U and Am (DU-Am) oxide fuel pin was performed for Pu denaturing in the framework of the protected plutonium production based on the irradiation analyses of the DU samples irradiated in the environment of broad range of neutron energy in the experimental fast reactor Joyo. From the results of irradiation analyses of DU, it was confirmed that there is a strong dependence of transmutation behaviour of DU on the ratio of neutron flux in the resonance region to the total neutron flux, namely resonance neutron ratio, even in a fast reactor. Also, it was confirmed that there is a strong effect of sample material form and shape on generated Pu nuclide inventory especially near the reflector area (>20% resonance neutron ratio), because of the intensive self-shielding of ^{238}U, though less is expected for ^{241}Am. Sensitivity study of hypothetical DU-Am oxide fuel pellet irradiation on neutron energy and burn-up was performed to evaluate significant gradient of radial ^{238}Pu isotopic composition profile (e.g. from 12% to 18% distribution in 3% Am doping, in 30% resonance neutron ratio and in the neutron fluence of 4.0×10^{22} n/cm^2 inside a large pellet with softened neutron spectrum), and vulnerability of the fuel pellet surface in terms of Pu denaturing was revealed. Design consideration of radial zoning of ^{241}Am content was introduced to flatten the radial distribution of isotopic composition of Pu. The results of radial zoning of ^{241}Am (4% and 3% Am in the outer and inner zone of DU-Am oxide fuel pellet) in hypothetical irradiation neutronics analysis showed the radial profile of produced Pu is over 15 at.% of ^{238}Pu isotopic composition in any zone and meets the published criterion based on decay heat of Pu to impede utilization to fission explosive devices.

13/03266 Fuel burnup analysis for the Moroccan TRIGA research reactor

El Bakkari, B. *et al. Annals of Nuclear Energy*, 2013, 51, 112–119.

The fundamental advantage and main reason to use Monte Carlo methods for burnup calculations is the possibility to generate extremely accurate burnup dependent one group cross-sections and neutron fluxes for arbitrary core and fuel geometries. Yet, a set of values determined for a material at a given position and time remains accurate only in a local region, in which neutron spectrum and flux vary weakly – and only for a limited period of time, during which changes of the local isotopic composition are minor. This paper presents the approach of fuel burnup evaluation used at the Moroccan TRIGA Mark II research reactor. The approach is essentially based upon the utilization of BUCAL1, an in-house developed burnup code. BUCAL1 is a FORTRAN computer code designed to aid in analysis, prediction, and optimization of fuel burnup performance in nuclear reactors. The code was developed to incorporate the neutron absorption reaction tally information generated directly by MCNP5 code in the calculation of fissioned or neutron-transmuted isotopes for multi-fuelled regions. The fuel cycle length and changes in several core parameters such as: core excess reactivity, control rods position, fluxes at the irradiation positions, axial and radial power factors and other parameters are estimated. Besides, this study gives valuable insight into the behaviour of the reactor and will ensure better utilization and operation of the reactor during its life-time and it will allow the establishment of strategic planning for fuel management such as shuffling and/or reloading schemes and its safe implementation.

13/03267 Improvement of LWR thermal margins by introducing thorium

Lau, C. W. *et al. Progress in Nuclear Energy*, 2012, 61, 48–56.

The use of thorium in pressurized water reactor fuel assemblies is investigated in this paper. The novelty of the reported work is to study a fuel design primarily intended to control the excess of reactivity at beginning of life, and flatten the intra-assembly power distribution rather than converting fertile Th-232 into fissile U-233. The fuel assembly is a traditional 17×17 pressurized water reactor fuel design. The majority of the fuel pins contain a mixture of uranium and thorium oxides, while a few fuel pins contain a mixture between uranium and gadolinium oxides. The calculation were performed by two-dimensional transport calculations with the Studsvik Scandpower CASMO-4E code in order to determine the main neutronic properties of the new fuel design, compared with the traditional uranium-based fuel assembly containing gadolinium used as reference. The majority of the neutronic properties of the uranium–thorium-based fuel assembly were similar to the reference fuel assembly. The Doppler and the moderator temperature coefficients of reactivity were found to be appreciably more negative in the uranium–thorium-based design, but still within acceptable limits. One advantage of this new uranium–thorium-based design is a reduction of the pin peak power at beginning of life, because of smaller amount of gadolinium being used. This is important from an operational and safety viewpoint, since the margin to departure from nucleate boiling becomes larger. Consequently, this new type of thorium-based fuel assembly shows advantageous properties for use in power-uprated cores.

13/03268 Microbial processing of apatite rich low grade Indian uranium ore in bioreactor

Abhilash, and Pandey, B. D. *Bioresource Technology*, 2013, 128, 619–623.

Bioreactor leaching using enriched culture of *Acidithiobacillus ferrooxidans* and *Leptosprillium ferrooxidans* was investigated for the apatite rich Indian (Narwapahar) uranium ore. Bioreactor leaching of Narwapahar ore of $>45\,\mu\mathrm{m}$ size at pH 2.0 and 10% (w/v) PD using 10% (v/v) inoculum of the bacterium at 35 °C (*A. ferrooxidans*) and 40 °C (*L. ferrooxidans*), solubilized 57% and 63% uranium in 5 days, respectively; the E_{SCE} values being 561 and 588 mV. Leaching kinetics improved so much so that ~83% uranium was recovered in just 10 h with 10% inoculum of *A. ferrooxidans* containing biogenic Fe^{3+}; at 20% PD uranium recovery rose to 87%. Role of temperature (25–40 °C) was noticed with 90.3% uranium bioleaching in 10 h at 40 °C with *L. ferrooxidans* as against 77% leaching with *A. ferrooxidans* at pH 2.0, 40 °C and 20% (w/v) PD.

13/03269 Quench of ITER poloidal field coils: influence of some initiation parameters on thermo-hydraulic detection signals and main impact on cryogenic system

Nicollet, S. *et al. Cryogenics*, 2013, 53, 86–93.

In case of a magnet quench, the primary quench detection system is classically based on voltage detection. In addition, a secondary quench detection is required and it could rely on signals of thermohydraulic nature. This study focuses on poloidal field coil PF5 as it has the highest magnetic field value along the conductor. Results of some parametric studies are presented and the influence of the initiation parameters of the quench (energy, location and length of heat deposition, time duration for detection). The possibility of a secondary thermohydraulic detection and the main impact on cryogenic system are analysed and discussed.

13/03270 Radiation shielding properties of concrete with electric arc furnace slag aggregates and steel shots

Maslehuddin, M. *et al. Annals of Nuclear Energy*, 2013, 53, 192–196.

Heavyweight concrete, prepared with a mixture of concrete and heavyweight aggregates or metallic components, is generally used for radiation shielding purposes. In the present study the radiation shielding properties of concrete prepared with electric arc furnace slag aggregates (EAFSAs) and steel shots, was investigated. The results indicated that concrete mixed with 50% EAFSA and 50% steel shots meets the weight and radiation requirements. The use of 50% EAFSA results in a decrease in the cost of concrete and also conserves a useful material, such as iron ore.

13/03271 Reactor core heterogeneity effects on radionuclide inventory

Obaidurrahman, K. and Gupta, S. K. *Annals of Nuclear Energy*, 2013, 53, 244–253.

Understanding fission product behaviour is an important aspect of nuclear safety studies. A nuclear reactor core contains complex mixture of fuel elements with different levels of enrichment, power and burnup. Conventional method of core radionuclide inventory estimation is based on use of homogenized core parameters like burnup, enrichment, specific power, etc. This approach does not reveal the variation in radionuclide density among different fuel elements within the core. The present work aims to bridge this knowledge gap by estimating the distribution of radionuclides in the nuclear reactor core taking into account the heterogeneity of the core explicitly. The analysis has brought out peak radionuclide density in the core which can be helpful in appropriate estimation of the radiological release in the accidental scenarios involving failures of few fuel assemblies. A quantitative comparison of total core inventory estimated based conventional core average parameters and detailed core inventory using individual fuel assembly inventory estimate has been made.

13/03272 Space–time convergence analysis on BWR stability using TRACE/PARCS

Gajev, I. *et al. Annals of Nuclear Energy*, 2013, 51, 295–306.

Unstable behaviour of boiling water reactors (BWRs) is known to occur during operation at certain power and flow conditions. Even though BWR instability is not a severe safety concern, it could cause reactor scram and significantly decrease the economic performance of the plant. This paper aims to (a) quantify TRACE/PARCS space–time discretization error for simulation of BWR stability, (b) establish space (nodalization) and time discretization necessary for space–time converged model and (c) show that the space–time converged model gives more reliable results for both stable and unstable reactor. The space–time converged model is obtained when further refinement of numerical discretization parameters (nodalization and time step) has negligible effect on the solution. The study is significant because performing a space–time convergence analysis is a necessary step of qualification of the TRACE/PARCS model, and use of the space–time converged model increases confidence in the prediction of BWR stability.

13/03273 Studies on disintegrating spherical fuel elements of high temperature gas-cooled reactor by a [an] electrochemical method

Tian, L. *et al. Journal of Nuclear Materials*, 2013, 432, (1–3), 113–119.

Spherical fuel elements of a high temperature gas-cooled reactor were disintegrated through an electrochemical method with NaNO_3 as electrolyte. The X-ray diffraction spectra and total carbon contents of the graphite fragments were determined, and the results agreed with those from simulated fuel elements. After conducting the characterization analysis and the leaching experiment of coated fuel particles, the uranium concentrations of leaching solutions and spent electrolyte were found to be at background levels. The results demonstrate the effectiveness of the improved electrochemical method with NaNO_3 as electrolyte in disintegrating the unirradiated fuel elements without any damage to the coated fuel particles. Moreover, the method avoided unexpected radioactivity contamination to the graphite matrix and spent electrolyte.

13/03274 Study of oxygen mass transfer coefficient and oxygen uptake rate in a stirred tank reactor for uranium ore bioleaching

Zokaei-Kadijani, S. *et al. Annals of Nuclear Energy*, 2013, 53, 280–287.

In this work, the volumetric oxygen mass transfer coefficient and the oxygen uptake rate (OUR) were studied for uranium ore bioleaching process by *Acidthiobacillus ferrooxidans* in a stirred tank reactor. The Box-Bohnken design method was used to study the effect of operating parameters on the oxygen mass transfer coefficient. The investigated factors were agitation speed (rpm), aeration rate (vvm) and pulp density (percentage weight/volume) of the stirred tank reactor. Analysis of experimental results showed that the oxygen mass transfer coefficient had low dependence on biomass concentration but had higher dependence on the agitation speed, aeration rate and pulp density. The obtained biological enhancement factors were equal to ones in experiments. On the other hand, the obtained values for Damkohler number ($Da < 0.468$) indicated that the process was limited by the biochemical reaction rate. Experimental results obtained for oxygen mass transfer coefficient were correlated with the empirical relations in earlier studies. Due to the high relative error in the correlation of an earlier study, that correlation was corrected and the coefficient of determination was calculated to be 89%. The modified correlation has been obtained based on a wide range of operating conditions, which can be used to determine the mass transfer coefficient in a bioreactor.

13/03275 The application of systems engineering principles to the prioritization of sustainable nuclear fuel cycle options

Price, R. R. *et al. Energy Policy*, 2013, 53, 205–217.

This study investigates the implementation of the principles of systems engineering in the US Department of Energy's fuel cycle technologies (FCT) program to provide a framework for achieving its long-term mission of demonstrating and deploying sustainable nuclear fuel cycle options. A fuel cycle 'screening' methodology is introduced that provides a systematic, objective, and traceable method for evaluating and categorizing nuclear fuel cycles according to their performance in meeting sustainability objectives. The goal of the systems engineering approach is to transparently define and justify the research and development (R&D) necessary to deploy sustainable fuel cycle technologies for a given set of national policy objectives. The approach provides a path for more efficient use of limited R&D resources and facilitates dialogue among a variety of stakeholder groups interested in US energy policy. Furthermore, the use of systems engineering principles will allow the FCT program to more rapidly adapt to future policy changes, including any decisions based on recommendations of the Blue Ribbon Commission on America's Nuclear Future. Specifically, if the relative importance of policy objectives changes, the FCT Program will have a structured process to rapidly determine how this impacts potential fuel cycle performance and the prioritization of needed R&D for associated technologies.

13/03276 The impact of time dependant [dependent] spectra on fusion blanket burn-up

Morgan, L. and Pasley, J. *Fusion Engineering and Design*, 2013, 88, (2), 100–105.

Knowledge of nuclide burn-up within tritium breeding blankets has a crucial part to play in the safety, reliability and efficiency of fusion reactors. The modelling of burn-up requires a series of neutron transport calculations which can compute the reaction rate either directly, via Monte Carlo estimators, or by implementing the multigroup method. These reaction rates can then be directly substituted into the burn-up equations, which can calculate nuclide number densities after a specified period of burn-up. The material burn-up will change the neutron spectra and the rate of nuclear reactions. Hence, a new neutron transport calculation needs to be performed after burn-up and the sequence is repeated for several time-steps. Radiation transport calculations are computationally expensive, therefore the minimization of reaction rate calculations via Monte Carlo simulations is desirable. Thus, time intervals between Monte Carlo simulations should be as large as possible. This paper addresses the effect of neutron spectra on the burn-up of parent and daughter nuclides found in EUROFER steel and the tritium self-sufficiency time. Using a spherical reactor geometry with lithium–lead tritium breeding material, a neutron spectrum is computed at time = 0 and time = 2 years after a detailed depletion calculation using single-day time intervals. These two spectra are then used to calculate reaction rates for every isotope listed within the EAF2005 database using the FISPACT code. The results show that the difference in nuclide number densities are less than 11% for all nuclides within the database and less than 4% for all fusion relevant nuclides. Using the same methodology as the first model, EUROFER parent and daughter nuclide number densities produced by each neutron spectra are compared. This study found that the change in burn-up for parent nuclides is statistically insignificant. However, the difference in daughter nuclide production is significant, especially for Rh, Ru, Re, Os, Pt and Ir where the differences range from 20% to 504%. Thus, in order to model the metallurgical properties of steels within fusion blankets over time, a multiple transport-burn-up depletion code (such as used by FATI, VESTA or MONTEBURNS) must be implemented. The final part of this work studied the effect of time-step interval (used to update neutron spectra) on the tritium self-sufficiency time of a blanket. The FATI depletion code modelled the same geometry as in part 1 of the study, however time-steps ranging from 1 day to approximately 800 days were used to predict when the blanket would cease to be able to breed enough tritium to sustain the fusion reactor. The single time-step model (i.e. where a constant neutron spectrum is used for the entire simulation) underestimated the tritium self-sufficiency time of the blanket by approximately 70%. Only time-steps less than 1 month produce a self-sufficiency time which is within 5% accuracy. Hence, this work suggests that spectra time-stepping is important in the modelling of tritium production with solid breeders.

13/03277 Thermal–hydraulic and safety analysis for Chinese helium-cooled solid breeder TBM cooling system

Wang, J. *et al. Fusion Engineering and Design*, 2013, 88, (1), 33–41.

The thermal–hydraulic behaviour and safety performance of the Chinese helium-cooled solid breeder (CH HCSB) test blanket module (TBM) with helium cooling system (HCS) has been studied using RELAP5/Mod3.4 code. According to accident analysis specification for TBM, two design basis accidents including loss of off-site power and TBM first wall (FW) ex-vessel coolant pipe break are investigated. The influences of different break locations and plasma termination behaviours are analysed comprehensively. The results show that natural circulation is established in helium cooling circuit and the TBM can be cooled effectively after loss of off-site power. It is much more critical when the pipe break occurs at the downstream side of the circulator compared with that of upstream side of the circulator. In case of a more serious accident that the ex-vessel break extends to the TBM FW, the results reveal that TBM could be cooled down by natural circulation and radiation. In addition, at the beginning of ex-vessel loss of coolant accident (LOCA), large temperature difference between break and intact TBM FW pipes is found. The accidental results finally show that the integrity of the FW can be guaranteed if the plasma is terminated with a 3 s delay time by fusion power shutdown system (FPSS) in the case of ex-vessel LOCA.

13/03278 Uncertainty analysis of criticality safety for the plate type fuel assembly storage rack

Han, T. Y. *et al. Annals of Nuclear Energy*, 2013, 53, 82–89.

To evaluate the criticality safety of the fresh and the spent fuel storage racks in an open pool type research reactor designed by KAERI, the upper subcriticality limit (USL) analysis was carried out. First, the bias and its uncertainty of MCNP code system with ENDF/B-VII library were evaluated using the calculation results of the 183 benchmark experiments. The criticality calculations for the fuel storage rack are carried out under a normal state, an increased water temperature, a fuel assembly drop, and an eccentric insertion which can affect the criticality. Considering biases and uncertainties for the MCNP code system, abnormal conditions, and the manufacturing tolerance of the cell tube thickness, the USL value that can guarantee sufficient subcriticality is determined. It was found that the criticality of the fresh and the spent fuel storage racks currently designed satisfy the USL condition. Additionally, it was concluded that the pitch size of a fresh fuel storage rack can be reduced for efficient space availability, and even under a worst case in which the fresh storage rack is surrounded by a lower water density and the smallest pitch size satisfies the USL conditions.

13/03279 Uranium-bearing phases in a U-mill disposal site in Northern Canada: products of the interaction between leachate/raffinate and tailings material

Schindler, M. *et al. Applied Geochemistry*, 2013, 29, 151–161.

The above ground tailings management facility (AGTMF) is a licensed tailings receiving facility at the Key Lake mine site, Northern Saskatchewan, Canada. Tailings within the AGTMF were deposited between 1983 and 1995 and are derived from mining and milling of the Gaertner and Deilmann ore-bodies at Key Lake. The tailings are primarily composed of quartz, phyllosilicate and clay gangue minerals, minor amounts of Ni–Co–S-arsenides, iron oxide minerals and gypsum. They typically contain U concentrations on the order of between 50 and 300 μg/g U. A small area of the AGTMF receives occasional mill-process upset solutions with an initial pH range of 2–6. The solutions contain elevated activities of U-bearing aqueous-species and are rapidly buffered to neutral and sub-alkaline pH values during interaction with surroundings tailings solids having a pH of approximately 10. This buffering and neutralization process results in the precipitation of gypsum and minor amounts of uranyl minerals. Phases of the autunite-group (chernikovite, $(H_3O)[(UO_2)(PO_4)](H_2O)_3$ and troegerite, $(H_3O)[(UO_2)(AsO_4)]$ $(H_2O)_3$ with minor NH_4^+) occur predominantly in the gypsum matrix but can also occur as crusts on silicates. The occurrence of troegerite is due to elevated concentrations of As within the deposited tailings solids. Surface alteration on phyllosilicates within tailings affected by the mill process solutions results in elevated concentrations of K at the phyllosilicate–water interface, which are ideal nucleation sites for the formation of single crystals of zippeite, $K_3(H_2O)_3[(UO_2)_4(SO_4)_2O_3(OH)]$. Use of NH_4-sulfates and ammonia in the extraction and yellow-cake precipitation cycles and subsequent entrainment of $(NH_4)^+$ species in the tailings results in the occurrence of (NH_4)-bearing phases of the zippeite- and autunite-group. Literature data on dissolution features, dissolution kinetics and mineral solubilities suggests that the minerals of the autunite group control the mobility of U in the contact zone between the mill-process solutions and the tailings.

Economics, policy, supplies, forecasts

13/03280 A comparative institutional analysis of the Fukushima nuclear disaster: lessons and policy implications

Aoki, M. and Rothwell, G. *Energy Policy*, 2013, 53, 240–247.

This paper analyses the causes, responses, and consequences of the Fukushima nuclear power plant accident (March 2011) by comparing these with Three Mile Island (March 1979) and Chernobyl (April 1986). The authors identify three generic modes of organizational coordination: modular, vertical, and horizontal. By relying on comparative institutional analysis, they compare the modes' performance characteristics in terms of short-term and long-term coordination, preparedness for shocks, and responsiveness to shocks. They then derive general lessons, including the identification of three shortcomings of integrated Japanese electric utilities: (1) decision instability that can lead to system failure after a large shock, (2) poor incentives to innovate, and (3) the lack of defence-in-depth strategies for accidents. The suggested policy response is to introduce an independent nuclear safety commission, and an independent system operator to coordinate buyers and sellers on publicly owned transmission grids. Without an independent safety regulator, or a very well established 'safety culture,' profit-maximizing behaviour by an entrenched electricity monopoly will not necessarily lead to a social optimum with regard to nuclear power plant safety. All countries considering continued operation or expansion of their nuclear power industries must strive to establish independent, competent, and respected safety regulators, or prepare for nuclear power plant accidents.

13/03281 A proactive alarm reduction method and its human factors validation test for a main control room for SMART

Jang, G.-s. *et al. Annals of Nuclear Energy*, 2013, 51, 125–134.

Conventional alarm systems tend to overwhelm operators during a transient because of a large number of nearly simultaneous annunciator activations with varying degrees of relevance to operator tasks. Thus, alarm processing techniques have developed to support operators in coping with the volume of alarms, to identify which alarms are significant, and to reduce the need for operators to infer the plant conditions. This paper proposes a proactive alarm reduction method for SMART (System-integrated Modular Advanced ReacTor) whereby based on the contents of the past operating effects alarm reduction is carried out during the next transient. The authors designed and implemented the proactive alarm reduction system and constructed the environment for the human factors validation test. Also, eight subjects actually working in a nuclear power plant tested the practical effectiveness of the proposed proactive alarm reduction method according to the procedure of human factors validation test under a dynamic simulation of a partial scope for a nuclear power plant.

13/03282 A survey of dynamic methodologies for probabilistic safety assessment of nuclear power plants

Aldemir, T. *Annals of Nuclear Energy*, 2013, 52, 113–124.

Dynamic methodologies for probabilistic safety assessment (PSA) are defined as those which use a time-dependent phenomenological model of system evolution along with its stochastic behaviour to account for possible dependencies between failure events. Over the past 30 years, numerous concerns have been raised in the literature regarding the capability of the traditional static modelling approaches such as the event-tree/fault-tree methodology to adequately account for the impact of process/hardware/software/firmware/human interactions on the stochastic system behaviour. A survey of the types of dynamic PSA methodologies proposed to date is presented, as well as a brief summary of an example application for the PSA modelling of a digital feedwater control system of an operating pressurized water reactor. The use of dynamic methodologies for PSA modelling of passive components and phenomenological uncertainties are also discussed.

13/03283 Economical analysis of an alternative strategy for CO_2 mitigation based on nuclear power

Alonso, G. and del Valle, E. *Energy*, 2013, 52, 66–76.

Many countries are pursuing greenhouse gas mitigation policies resulting in the increase of use of renewable sources in the electricity sector to mitigate CO_2 emissions. Nuclear energy is a non-emitting CO_2 source that could be used as part of that policy. However, its main drawback is the high investment required for its deployment. On the other hand, wind power is the clean source preferred option to mitigate CO_2 emissions. However, due to its intermittence backup power is needed, in most of the cases it must be provided with combined cycle thermal plants using natural gas. This study performs an economical comparison of a hypothetical implementation of a nuclear strategy to meet the same CO_2 emissions reduction goal that has been obtained by the actual Spanish strategy (2005–2010) based on wind power. The investment required in both strategies is assessed under different investment scenarios and electricity production conditions for nuclear power. Also, the cost of electricity generation is compared for both strategies.

13/03284 Fukushima and thereafter: reassessment of risks of nuclear power

Srinivasan, T. N. and Gopi Rethinaraj, T. S. *Energy Policy*, 2013, 52, 726–736.

The Fukushima nuclear accident on 11 March 2011 in Japan has severely dented the prospects of growth of civilian nuclear power in many countries. Although Japan's worst nuclear accident was triggered by an unprecedented earthquake and tsunami, inadequate safety countermeasures and collusive ties between the plant operators, regulators, and government officials left the Fukushima Daiichi nuclear plant beyond redemption. A critical examination of the accident reveals that the accumulation of various technical and institutional lapses only compounded the nuclear disaster. Besides technical fixes such as enhanced engineering safety features and better siting choices, the critical ingredient for safe operation of nuclear reactors lie in the quality of human training and transparency of the nuclear regulatory process that keeps public interest – not utility interest – at the forefront. The need for a credible and transparent analysis of the social benefits and risks of nuclear power is emphasized in the context of energy portfolio choice.

13/03285 Historical insights in the development of best estimate plus uncertainty safety analysis

Wilson, G. E. *Annals of Nuclear Energy*, 2013, 52, 2–9.

Requirements related to licensing and regulation submittals for US commercial nuclear reactors were originally based on what was believed to be the most problematic accident scenarios, conservative safety limits and prescribed analysis methods. However, by the 1980s the large database of experimental and analytical research, and actual reactor operation indicated the initial strongly conservative approach was somewhat misdirected and sometimes even gave non-conservative results. Accordingly, an increasing motivation existed to develop a safety analysis strategy that reflected risk-based licensing principals. The first successful advancement of such an approach was embedded in the code scaling applicability and uncertainty, and phenomena identification and ranking table methodologies and accepted by regulation arms of the US Nuclear Regulatory Commission. This strategy is commonly termed the best estimate plus uncertainty methodology. A historical perspective of the original code scaling applicability and uncertainty, and phenomena identification and ranking table processes is provided, as is description of the subsequent improvements through 2010 in best estimate plus uncertainty methodologies.

13/03286 Improved framework for the maintenance of the JET intershot analysis chain

Dodt, D. *et al. Fusion Engineering and Design*, 2013, 88, (2), 79–84.

At the JET experiment data from routine diagnostics is analysed automatically by a suite of codes within minutes after operation. The maintenance of these interdependent codes and the provision of a consistent state of the physics database over many experimental campaigns against a backdrop of continuous hardware and software updates, requires well-defined maintenance and validation procedures. In this paper, the development of a new generation of maintenance tools using distributed version control and a work-flow following the principle of continuous integration is described.

13/03287 Recent progress in research on tungsten materials for nuclear fusion applications in Europe

Rieth, M. *et al. Journal of Nuclear Materials*, 2013, 432, (1–3), 482–500.

The current magnetic confinement nuclear fusion power reactor concepts going beyond ITER are based on assumptions about the availability of materials with extreme mechanical, heat, and neutron load capacity. In Europe, the development of such structural and armour materials together with the necessary production, machining, and fabrication technologies is pursued within the EFDA long-term fusion materials programme. This paper reviews the progress of work within the programme in the area of tungsten and tungsten alloys. Results, conclusions, and future projections are summarized for each of the programme's main subtopics, which are: (1) fabrication, (2) structural W materials, (3) W armour materials, and (4) materials science and modelling. It gives a detailed overview of the latest results on materials research, fabrication processes, joining options, high heat flux testing, plasticity studies, modelling, and validation experiments.

13/03288 Simulations of unprotected loss of heat sink and combination of events accidents for a molten salt reactor

Guo, Z. *et al. Annals of Nuclear Energy*, 2013, 53, 309–319.

The molten salt reactor (MSR) is one of the Generation IV reactors. The fuel is dissolved in the carrier salt and circulates in the loop. The technologies are different from that in the solid-fuel reactors. In this work, the attention is focused on development of safety analysis tool for the MSRs. A single channel model, a heat transfer model, a heat sink model and a liquid-fuel point kinetic model that takes into account the effect of circulation are employed. The validation of this code is done with the experimental data of pump coastdown and startup in MSRE. The unprotected loss of heat sink (ULOHS), combination of ULOHS and unprotected loss of flow (ULOF) are performed on the molten salt actinide recycler and transmuter (MOSART). This work aims to study temperature fluctuation, corresponding power change, effect of flow delayed neutron precursors and temperature reactivity feedback in transient accident to examine the inherent safety design of MOSART. The transient results reveal that the large negative temperature feedback coefficients guarantee MOSART inherent safety and the range of temperature is within the safety margin in case of combination of accidental events.

13/03289 The ethics of nuclear power: social experiments, intergenerational justice, and emotions

Taebi, B. *et al. Energy Policy*, 2012, 51, 202–206.

This paper argues that traditional approaches to risk assessment should be supplemented by an explicit discussion of the moral acceptability of nuclear technology and the risks it poses. The introduction of nuclear energy in society should be seen as an on-going social experiment, whose (moral) acceptability should continuously be addressed. Given the long-term risks of nuclear energy, intergenerational justice should be explicitly included in such an analysis. This will also have implications for nuclear power policies. Furthermore, emotions such as sympathy and feelings of responsibility can provide moral insights; they should be taken seriously in the debate about nuclear energy rather than being dismissed as irrational distractions as is currently the case. These proposed reforms would help society to move beyond the usual stalemate in the debate about nuclear power.

13/03290 V&V-based remaining fault estimation model for safety–critical software of a nuclear power plant

Eom, H.-s. *et al. Annals of Nuclear Energy*, 2013, 51, 38–49.

Quantitative software reliability measurement approaches have some limitations in demonstrating the proper level of reliability in cases of safety–critical software. One of the more promising alternatives is the use of software development quality information. Particularly in the nuclear industry, regulatory bodies in most countries use both probabilistic and deterministic measures for ensuring the reliability of safety-grade digital computers in nuclear power plants. The point of deterministic criteria is to assess the whole development process and its related activities during the software development life cycle for the acceptance of safety–critical software. In addition software verification and validation (V&V) plays an important role in this process. Taking this into account, a V&V-based fault estimation method using Bayesian nets is proposed to estimate the remaining faults for safety–critical software after the software development life cycle is completed. By modelling the fault insertion and elimination processes during the whole development phases, the proposed method systematically estimates the expected number of remaining faults.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

13/03291 A contribution to the wireless transmission of power

Tucker, C. A. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 235–242.

A resonant transmitter–receiver system is described for the wireless transmission of energy at a useful distance for grid-coordinate power and information. Experimental results are given showing delivery of power of an unmodified Tesla resonator contrasted with a modified version achieving improved efficiency over a 4 m range. A theoretical basis is provided to back up the experimental results obtained and to link the study with previous research in the field. A number of potential routes are suggested for further investigations and some possible applications of the technology are considered.

13/03292 A natural battery based on lake water and its soil bank

Bhuyan, S. and Hu, J. *Energy*, 2013, 51, 395–399.

This study reports a natural battery constructed by lake water and its soil bank. A direct current open-circuit electric voltage and short-circuit current is generated between two metal electrodes dipped inside lake water and its soil bank. The open-circuit voltage, short-circuit electric current and maximum output power are up to 486 mV, 70 μA and 8.2 μW, depending on the distance from the metal electrode inserted into soil to the one immersed in lake water. The small power of the battery is generated by the pH value difference between the lake water and soil bank, and the oxidation of organic matter around the electrode in soil. The natural battery provides an easy and essential method to harvest small energy from the environment for the drive of low power electronic systems.

13/03293 A new approach for optimum DG placement and sizing based on voltage stability maximization and minimization of power losses

Aman, M. M. *et al. Energy Conversion and Management*, 2013, 70, 202–210.

Distributed generation (DG) placement on the basis of minimization of losses and maximization of system voltage stability are two different approaches, discussed in research. In the new proposed algorithm, a multi-objective approach is used to combine the both approaches together. Minimization of power losses and maximization of voltage stability due to finding weakest voltage bus as well as due to weakest link in the system are considered in the fitness function. Particle swarm optimization algorithm is used in this paper to solve the multi-objective problem. This paper will also compare the propose method with existing DG placement methods. From results, the proposed method is found more advantageous than the previous work in terms of voltage profile improvement, maximization of system loadability, reduction in power system losses and maximization of bus and line voltage stability. The results are validated on 12-, 30-, 33- and 69-bus radial distribution networks and also discussed in detailed.

13/03294 All-solid-state flexible thin film supercapacitor based on Mn_3O_4 stacked nanosheets with gel electrolyte

Dubal, D. P. and Holze, R. *Energy*, 2013, 51, 407–412.

Recently, much effort has been devoted to accomplish thin, lightweight and flexible energy-storage devices for wearable electronics. Here, the authors demonstrate a novel kind of thin all-solid-state supercapacitor configuration with an extremely simple process using two slightly separated stacked nanosheets-like Mn_3O_4 electrodes well solidified in the H_2SO_4–polyvinyl alcohol gel electrolyte. This integrate device shows a high specific capacitance of $127\,F\,g^{-1}$ for the electrode materials with good power and energy density values. These flexible and all-solid-state Mn_3O_4 supercapacitors bring new design opportunities of device configuration for future energy-storage devices. This investigation reported for the first time that Mn_3O_4 is one of the most promising materials for the fabrication of all solid state thin film supercapacitors.

13/03295 Building-integrated microgrid: advanced local energy management for forthcoming smart power grid communication

Sechilariu, M. *et al. Energy and Buildings*, 2013, 59, 236–243.

In an increasingly constrained context with severe requirements of quality, safety and environment respect, a building-integrated photovoltaic (BIPV) involves advanced local energy management rather than photovoltaic (PV) power permanent grid injection. This paper focus on building-integrated microgrid (BIMG) design and implementation applied to BIPV system with energy storage and smart grid communication. The goal is to propose power balancing strategy with smart grid interaction, aiming at reducing grid peak consumption, avoiding undesirable grid power injection, making full use of local PV production. The energy management is carried out considering grid time-of-use tariffs, grid access limits, storage capacity, load and PV power shedding if necessary. Based on experimental platform, the results show that the system maintains stability and confirm the relevance of the proposed local energy management giving perspectives on better integration of small PV plant in power grid.

13/03296 Combined photovoltaic and unified power quality controller to improve power quality

Reisi, A. R. *et al. Solar Energy*, 2013, 88, 154–162.

Rapid growth of non-linear loads leads to lots of power quality problems such as harmonics, unbalance operation and excessive source-end neutral current in three-phase supplying networks. This paper proposes a combined photovoltaic (PV) unified power quality controller (UPQC) for compensation of source voltage deficiencies (e.g. sag and swell). Meanwhile, considering the advanced generalized theory of instantaneous power (A-GTIP) algorithm, the proposed UPQC leads to suppress grid-end current harmonics caused by the distorted–unbalanced load-terminal voltages. Hence, the grid-end currents could remain purely sinusoidal. Additionally, using combined UPQC and PV system there will be capital investment savings since one less converter will be used in comparison with separated UPQC and PV. In this paper a new maximum power point tracking (MPPT) algorithm is also proposed to efficiently improve the performance of the solar panels. Based on short circuit current estimation as the offline stage, and online perturbation and observation seeking method as the fine-tuning stage, this proposed MPPT method can successfully track the maximum power point of the solar panel and still remain straightforward for practical implementation. Various simulation results verify the performance of the combined PV–UPQC and the proposed MPPT method.

13/03297 Comparative investigation on microbial community and electricity generation in aerobic and anaerobic enriched MFCs

Quan, X.-c. *et al. Bioresource Technology*, 2013, 128, 259–265.

This study compared the difference in microbial community and power generation capacity of air-cathode MFCs enriched under anode aerobic and anaerobic conditions. Results showed that MFCs successfully started with continuous air inputting to anode chamber. The aerobic enriched MFC produced comparable and even more electricity with the fuels of acetate, glucose and ethanol compared to the anaerobic MFC when returning to anaerobic condition. The two MFCs showed a slightly different microbial community for anode biofilms (a similarity of 77%), but a highly similar microbial community (a similarity of 97%) for anolyte microbes. The anode biofilm of aerobic enriched MFC showed the presence of some specific bacteria closely related to *Clostridium sticklandii*, *Leucobacter komagatae* and *Microbacterium laevaniformans*. The anaerobic enriched MFC found the presence of a large number of yeast *Trichosporon* sp. This research demonstrates that it is possible to enrich oxygen-tolerant anode respiring bacteria through purposely aeration in anode chamber.

13/03298 Decentralized secondary voltage control using voltage drop compensator among power plants

da Silva, R. J. G. C. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 61–68.

This paper deals with the problem of voltage collapse in power systems by presenting a decentralized secondary voltage control. For this purpose the coordination between the joint voltage control available in the generation plants is used to control the voltage level at the transmission system by adjusting a compensation impedance. By using this approach, the generation plants become more sensitive to the system operating and configuration conditions. A sensitivity-based methodology to identify the most effective plants and the impedance value associated is presented. Some examples meant to explore the potential of the methodology are presented and discussed with the help of real systems.

13/03299 Electrochemically reduced graphene oxide sheets for use in high performance supercapacitors

Yang, J. *et al. Carbon*, 2013, 51, 36–44.

Graphene oxide (GO) was reduced by a rapid, effective and eco-friendly electrochemical method of repetitive cathodic cyclic potential cycling, without using any reducing reagents. The electrochemically reduced graphene oxide (ERGO) was characterized by UV–vis, EIS and zeta-potential measurements. Most of the oxygen functional groups in ERGO were successfully removed resulting in smaller charge transfer resistance. However, some electrochemically stable residuals still remained, enabling ERGO to facilitate electrolyte penetration and pseudocapacitance. Since ERGO was readily stabilized by cathodic potential cycling, it exhibited an outstanding stability in cycle life, nearly with no capacitive loss from the second cycle on. A specific capacitance of 223.6 F g^{-1} was achieved at 5 mV s^{-1}, which makes the ERGO a competitive material for electrochemical energy storage.

13/03300 Enhanced performance of solar-driven photovoltaic–thermoelectric hybrid system in an integrated design

Deng, Y. *et al. Solar Energy*, 2013, 88, 182–191.

A solar-driven hybrid generation system (HGS) in an integrated design is successfully fabricated, which consists of a silicon thin-film solar cell (STC), thermoelectric generators (TEGs) and a heat collector. STC absorbs parts of the solar energy and directly converts it into electric energy. The undesired waste heat from STC and parts of the solar energy are collected by the heat collector and conducted to TEG to produce thermoelectric conversion. The structure and the performance of HGS are discussed. A numerical simulation is also performed on TEG to obtain the distribution of heat flux using finite element method (FEM). The results show that the performances of TEG and STC are synchronously enhanced due to the integrated design. Especially the heat flux on the hot side of TEG integrated in HGS increases by more than tenfold. The total generated power of 393 mW is obtained in HGS, which is twice larger than that of single STC. The developed HGS is a promising power system which can effectively broaden the use of the solar spectrum and increase the power output in solar conversion.

13/03301 Evaluation of *Laminaria*-based microbial fuel cells (*Lb*Ms) for electricity production

Gadhamshetty, V. *et al. Bioresource Technology*, 2013, 127, 378–385.

Marine algae represents a sustainable feedstock in microbial fuel cells (MFCs) due to its low water and energy requirements for cultivation, higher capacity to sequester carbon dioxide, and high carbohydrate content. Two-compartment MFCs were evaluated under batch-fed mode using *Laminaria saccharina* as the model for algae-based electron donor, and mixed microbial consortia as the biocatalyst, in the anode compartment. The *Laminaria*-based MFCs (LBMs) were studied with three different pretreatment conditions for the *L. saccharina*: (i) autoclaving (auto), (ii) microwave irradiation (Micro), and (iii) as-received treatment (no-treat). A control was setup to establish base line performance for two-compartment MFCs using glucose as the electron donor in the anode. The performance of LBMs (250 mW/m^2 and 900 mA/m^2) was on par with glucose-based MFCs. AC impedance analysis revealed that the charge transfer resistance was at least 50-fold higher than the corresponding ohmic losses in both LBMs and glucose-based MFCs.

13/03302 Experimental analysis and optimization of key parameters of ZVS mode and its application in the proposed LLC converter designed for distributed power system application

Frivaldský, I. M. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 448–456.

This paper deals with experimental analysis of zero-voltage switching mode targeting high-frequency operation of chosen MOSFET type. After selection of specific type of transistor (IPW60R165CP) the experimental investigation was been made by changing parameters (e.g. dead-time, auxiliary capacitance of MOSFET, transistor current), that influence the ZVS commutation process. For these purposes the universal testing device was constructed, this was capable of securing realistic conditions for various types of commutation modes (hard switching, zero-voltage switching v(ZVS), zero-current switching). Following this, the best settings of commutation mode were utilized in the proposed LLC converter suited for distributed power system application. The prototype operated in the ZVS region with optimized parameters. Switching frequency was from 130 kHz (input voltage 325 Vdc) to 210 kHz (input voltage 415 Vdc) with an output power of 1500 W. It is clear from the results that experimental analysis of the ZVS commutation mode brings the expectation of transistor behaviour which was completely confirmed also in the case of experimental analysis of LLC resonant converter.

13/03303 Experimental evaluation of particle number emissions from wood combustion in a closed fireplace

Ozgen, S. *et al. Biomass and Bioenergy*, 2013, 50, 65–74.

Particulate matter emissions from a commercially available closed fireplace were determined in terms of particle number and the size distribution, employing a dilution sampling scheme capable of providing near-real-world emission situation. The time profile of the emissions was also traced together with the main gaseous species providing insight onto the particle formation mechanisms in relation with the varying combustion conditions in the batch-wise system. An average emission factor of 1.4×10^{15} # kg^{-1} (7.1×10^{13} # MJ^{-1}) was found for total number of particles. Nanoparticles (geometric mean diameter GMD = 28 nm) account for the 32% of the emissions, whereas larger particles (GMD = 127 nm) constitute the 68%. Number emissions were in strict relationship with the combustion conditions in the fireplace. The ignition phase is responsible for the 46% of the nanoparticle burden of the whole burning cycle. Larger particles are thought to be primary soot particles emitted during the flaming combustion phase and coated by condensing semivolatile organic species in the diluted and cooled flue gas.

13/03304 Functionalized carbon onions, detonation nanodiamond and mesoporous carbon as cathodes in Li-ion electrochemical energy storage devices

Gu, W. *et al. Carbon*, 2013, 53, 292–301.

Functionalization of carbon surface leads to the enhancement of ion storage capacity of carbon cathodes due to the additional pseudocapacitive reactions. In order to gain additional insights on the effects of the carbon specific surface area, porosity and oxygen-containing functional groups on their electrochemical performance, the authors have investigated thick (>150 μm) electrodes based on carbon onion nanopowder with and without functional groups present on carbon surface as well as nanodiamond soot and mesoporous activated carbon. Oxidation of carbon onion surface was found to result in a 2.4–2.8-fold increase in their specific capacitance. The larger average pore size and the absence of micropores in carbon nanoparticles based electrodes resulted in a better rate performance compared to that of mesoporous activated carbon. However, significant self-discharge was observed in all the oxidized samples. The low electrode density combined with limited overall charge storage capacity of carbon samples resulted in a volumetric capacity of less than 23 mAh cm^{-3}, compared to 450–700 mAh cm^{-3} offered by state of the art high-density cathodes used in commercial Li-ion batteries. Even with further improvements, the estimations suggest that porous carbon cathodes will unlikely be able to offer more than 15% of the energy density of traditional cathodes.

13/03305 Inherent structural characteristic indices of power system networks

Sikiru, T. H. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 218–224.

Power equation relating an interconnected network is non-linear and normally solved iteratively. This only gives numerical solution of a load flow without providing information on the structural relationship between buses that governs the solution that ensured. The absence of this information is an obstacle to readily solving most of power system problems. This paper seeks to overcome this limitation by proposing inherent structural indices that describe power system networks. These indices are obtained from the partitioned Y-admittance matrix based on circuit theory representation of networks. With these structural indices, an alternative method to determining the location of a new generator in a network is proposed and demonstrated.

13/03306 Large scale templated synthesis of single-layered graphene with a high electrical capacitance

Wang, Y. *et al. Carbon*, 2013, 53, 245–251.

This study demonstrates that single graphene sheets can be easily synthesized in large amounts by using zeolite Ni-MCM-22 as a catalyst and template. The graphene has a large surface area, high conductivity, and controllable two-dimensional sizes. Its use in supercapacitor electrode materials reveals excellent electrochemical double layer capacitance and galvanostatic charge/discharge properties with specific capacitances of 233 F/g in aqueous KOH.

13/03307 Method for size optimisation of large wind–hydrogen systems with high penetration on power grids

Beccali, M. *et al. Applied Energy*, 2013, 102, 534–544.

Wind power generation is growing rapidly in many locations around the world. Power systems are able to absorb large amounts of wind capacity, but operational problems arise when the wind power penetration becomes high. Such factors as voltage dips, frequency variations, low power system stability, low reactive power and power flow imbalances reduce the economic value and represent a barrier to the unlimited development of wind energy. Hydrogen production from wind power that is not matched with hourly electricity demand appears to be an attractive storage option capable of providing a balancing service to the electricity generators and suppliers for mitigation of the negative impacts due to the random nature of wind. Because of its multi-functionality, hydrogen can be used directly as a fuel, mixed with methane, or transmitted through pipelines to the users. The aim of this paper is to produce useful suggestions for the planning, development and sizing of wind–hydrogen systems by taking into account the local and regional resources, demands, constraints and opportunities. This study considers both the economic and technological variables and describes an optimization method for analysing power systems in which part of the electricity generated by a grid-connected wind plant is used to produce hydrogen by electrolysis. An example application of this OM has been developed for a specific geographical area located in central Sicily. The results identify the potential and the limitations connected to cases that use excess wind power to produce hydrogen for civil applications.

13/03308 Micro-sources design of an intelligent building integrated with micro-grid

Zeng, Z. *et al. Energy and Buildings*, 2013, 57, 261–267.

An intelligent building integrated with micro-grids can provide a comfortable environment as well as accommodate low energy consumption targets. However, the output power of micro-sources in the micro-grid for intelligent building application is stochastic, uncertain and uncontrollable. Thus, the micro-source design of an intelligent building integrated with micro-grid is a significant issue. In this study, a mathematical model is proposed to optimize the capacities of micro-resources, which can harvest green energy from renewable energy resources (RERs) as much as possible. In this model, the energy cost coefficient (ECC) is set as the minimization objective function, F, which is defined as the ratio between energy cost of the intelligent building and the output energy of RESs. It is should be noted that ECC is different from a conventional optimum objective to minimize the cost of whole project, C. As a result, a multi-objective model associated with F and C is also discussed to satisfy different requirements and targets of numerous users. A numerical example is utilized to validate the feasibility of the proposed approach. Simultaneously, the Pareto fronts of the multi-objective model are obtained using linear interactive and general optimizer.

13/03309 MINLP model for optimizing electricity production from coal-fired power plants considering carbon management

Cristóbal, J. *et al. Energy Policy*, 2012, 51, 493–501.

In order to achieve the reduction in greenhouse gases committed in the Kyoto Protocol, countries must establish control policies and encourage industries to reduce their emissions. Two main options arise in a cap and trade framework: (i) buying/selling emission allowances; and (ii) reducing emissions by investing in abatement technologies. In this context, each industry must choose the best strategy considering its particular features. This work proposes a systematic tool to assist decision-makers in the design of coal-fired energy production with carbon management in existing power plants. The approach relies on a novel mixed integer non-linear program (MINLP) that minimizes the cost of electricity (COE) for a given price of CO_2 allowance on the trade market. The authors demonstrate the capabilities of this MINLP through a case study that addresses the retrofitting of a coal-fired power plant. Results show that the price of the CO_2 allowance on the market that effectively induce the investment in carbon capture falls in the range 22–30 \$/tCO_2eq depending on the quantity of allowances distributed for free. In this solution, carbon capture is accomplished by implementing the oxy-fuel combustion technology (which is preferred to the post-combustion capture using monoethanolamine as solvent).

13/03310 Multi-objective energy management of CHP (combined heat and power)-based micro-grid

Motevasel, M. *et al. Energy*, 2013, 51, 123–136.

In this paper, an IEMS (intelligent energy management system) was proposed the for optimal operation of a combined heat and power (CHP)-based micro-grid over a 24-hour time interval. The IEMS aims to find the optimal set points of distributed energy resources (DERs) and thermal and electrical storage systems, in such a way that the total operation cost and the net emission are minimized, simultaneously. For optimal operation of the micro-grid, a smart energy storage system (ESS) is introduced which consists of electrical and thermal storage systems. A comprehensive mathematical model for the ESS and also the economic and environmental objective functions are formulated. To solve the problem, an efficient modified bacterial foraging optimization (MBFO) algorithm is proposed. An interactive fuzzy satisfying method is also used to simulate the trade-off between conflicting objectives (cost and emission). To validate the performance of the proposed algorithm, the authors compared the MBFO algorithm with some other previously proposed analytical methods. Finally, the proposed IEMS was applied to a micro-grid which consisted of various DERs, a CHP system, an ESS and thermal and electrical loads. The results showed that the proposed IEMS can smartly cover the total electrical and thermal load demands with respect to economic and environmental criteria.

13/03311 Novel power electronic interface for grid-connected fuel cell power generation system

Wu, J.-C. *et al. Energy Conversion and Management*, 2013, 71, 227–234.

A novel power electronic interface for the grid-connected fuel cell power generation system is proposed in this paper. This power electronic interface is composed of a DC–DC power converter and a DC–AC inverter. A voltage doubler based topology is adopted to configure the DC–DC power converter to perform high step-up gain for boosting the output voltage of the fuel cell to a higher voltage. Moreover, the input current ripple of the fuel cell is suppressed by controlling the DC–DC power converter. The DC–AC inverter is configured by a dual buck power converter and a full-bridge power converter to generate a five-level AC output voltage. The DC–AC inverter can perform the functions of DC–AC power conversion and active power filtration. A 1.2 kW hardware prototype is developed to verify the performance of the proposed power electronic interface for the grid-connected fuel cell power generation system. The experimental results show that the proposed power electronic interface for the grid-connected fuel cell power generation system has the expected performance.

13/03312 Optimization of distributed generation capacities in buildings under uncertainty in load demand

Rezvan, A. T. *et al. Energy and Buildings*, 2013, 57, 58–64.

This paper presents a method to determine the optimum capacity of distributed generation technologies for buildings. The combined heat and power (CHP) unit has both absorption and electric chiller for cooling loads, and a supplementary boiler for heating loads. The demand is uncertain in the model. The underlying uncertainty is modelled using probabilistic theory. In this method, the expected value of the objective function is evaluated using numerical approaches. A simulation based optimization method is presented which can estimate the cost of system operation and find the appropriate design by means of stochastic programming. The effect of minimum economic turndown of the facilities is also discussed in this paper. The optimum capacity of distributed generation technologies has a great effect on the cost of the building. Therefore, the proposed method is applied for a hospital in Iran as a case study. The results show that the optimum capacities of CHP and absorption chiller decreases and the capacities of the electric chiller and boiler rise by an increase in demand uncertainty. In addition, the appropriate minimum economic turndown of facilities has a considerable effect on the overall system cost.

13/03313 Optimum capacity determination of stand-alone hybrid generation system considering cost and reliability

Chen, H.-C. *Applied Energy*, 2013, 103, 155–164.

The aim of this work is to present an optimization methodology for the installation capacity of a stand-alone hybrid generation system, taking into consideration the cost and reliability. First, on the basis of derived steady state models of a wind generator (WG), a photovoltaic array (PV), a battery and an inverter, the hybrid generation system is modelled for the purpose of capacity optimization. Second, the power system is analysed for determining both the system structure and the operation control strategy. Thirdly, according to hourly weather database of wind speed, temperature and solar irradiation, annual power generation capacity is estimated for the system match design in order that an annual power load demand can be met. The capacity determination of a hybrid generation system becomes complicated as a result of the uncertainty in the renewable energy together with load demand and the non-linearity of system components. Aimed at the power system reliability and the cost minimization, the capacity of a hybrid generation system is optimized by application of an adaptive genetic algorithm (AGA) to individual power generation units. A total cost investigation is made under various conditions, such as wind generator power curves, battery discharge depth and the loss of load probability (LOLP). At the end of this work, the capacity of a hybrid generation system is optimized at two installation sites, namely the offshore Orchid Island and Wuchi in Taiwan. The optimization scheme is validated to optimize power capacities of a photovoltaic array, a battery and a wind turbine generator with a relative computational simplicity.

13/03314 Performance assessment of a micro-cogeneration system under realistic operating conditions

Rosato, A. and Sibilio, S. *Energy Conversion and Management*, 2013, 70, 149–162.

The European parliament stated that high-efficiency cogeneration is a community priority given the potential benefits of cogeneration with regard to saving primary energy and reducing emissions. From this position, the performance of many micro-cogeneration systems has been assessed from an energy and environmental point of view. However, in most cases, the assessments have been performed by using technical data from manufacturers and/or experimental results measured during steady-state operation, without considering the inefficiencies related to the transient periods; in addition, few works have been devoted to analysing the system operation from an exergy-based point of view. In this paper the electric load-following operation of an internal combustion engine based micro-cogeneration unit with 6.0 kW as a nominal electric output has been experimentally investigated in electric load-following operation during a 24 h dynamic test with the application of a realistic daily load profile representing the Italian domestic non-HVAC electric demand for a multi-family house of five dwellings. The measured data have been compared with the data that would be associated with servicing the building with electricity from the central electric grid and heat from a natural gas fired boiler from an energy, exergy and environmental points of view.

13/03315 Process simulation and economic analysis of the calcium looping process (CLP) for hydrogen and electricity production from coal and natural gas

Connell, D. P. *et al. Fuel*, 2013, 105, 383–396.

The calcium looping process (CLP) is being developed to facilitate carbon dioxide (CO_2) capture during the production of hydrogen (H_2) from syngas. The process integrates CO_2, sulfur, and halide removal with the water–gas shift (WGS) reaction in a single-stage reactor. In the CLP, a regenerable calcium oxide (CaO) sorbent is used to chemically react with and remove CO_2 and other acid gases from syngas at high temperature (i.e. 550–700 °C). The removal of CO_2 drives the WGS reaction forward via Le Chatelier's principle, obviating the need for a WGS catalyst and enabling the production of high-purity H_2. The spent sorbent is heated in a calciner to regenerate CaO for reuse in the process and to release a concentrated CO_2 stream, which can be dried and sequestered. The regenerated sorbent is then reactivated in a hydrator, to improve its recyclability, before being reintroduced into the H_2 production reactor. Techno-economic analyses were performed to evaluate the application of the CLP to a coal-to-H_2 plant, a steam methane reforming (SMR) plant, and an integrated gasification-combined cycle (IGCC) plant, all including $\geq 90\%$ CO_2 capture. In each case, use of the CLP resulted in a 9–12% reduction in the cost of H_2 or cost of electricity when compared with the use of conventional CO_2 capture and WGS technologies. The economic advantage afforded by the CLP is realized because of the large amount of high-quality heat produced in the process, which is recovered to raise steam for electricity generation. This heat arises from the combustion of supplemental fuel in the CLP calciner and from the exothermic CO_2 removal, WGS, and hydration reactions, which are carried out at high temperature (i.e. ≥ 500 °C) in the CLP. As a result of recovering this heat, the CLP-based coal-to-H_2 and SMR plants, which are designed to produce 26,000 kg/h H_2, necessarily co-produce 320 MW_e and 190 MW_e of net electric power, respectively. Although the CLP can reduce the cost of producing H_2 from coal, the resulting cost is still about 26% greater than the cost of H_2 produced from natural gas using conventional WGS and CO_2 capture technologies, assuming coal and natural gas prices of $1.55/GJ and $6.21/GJ, respectively. The lowest cost of H_2 with CO_2 capture for these fuel prices is achieved by applying the CLP to an SMR plant.

13/03316 Response surface method applied to the thermoeconomic optimization of a complex cogeneration system modeled in a process simulator

Pires, T. S. *et al. Energy*, 2013, 52, 44–54.

This work presents the application of a surrogate model – a response surface – to replace the objective function to be minimized in the thermoeconomic optimization of a complex thermal system modelled with the aid of an expert process simulator. The objective function accounts for fuel, capital, operation and maintenance costs of the thermal system, and depends on nine decision variables. The minimization task is performed through the computational integration of two professional programs, a process simulator and a mathematical platform. Five algorithms are used to perform the optimization: the pattern search and genetic algorithms, both available in the mathematical platform, plus three custom-coded algorithms, differential evolution, particle swarm and simulated annealing. A comparative analysis of the performance of all five methods is presented, together with a critical appraisal of the surrogate model effectiveness. In the course of the optimization procedure, the process simulator computes the thermodynamic properties of all flows of the thermal system and solves the mass and energy balances each time the objective function has to be evaluated. By handling a set of radial basis functions as an approximation model to the original computationally expensive objective function, it is found here that the number of function evaluations can be appreciably reduced without significant deviation of the optimal value. The present study indicates that, for a thermoeconomic system optimization problem with a large number of decision variables and/or a costly objective function, the application of the response surface surrogate may prove more efficient than the original simulation model, reducing substantially the computational time involved in the optimization.

13/03317 Small scale electricity generation from a portable biomass cookstove: prototype design and preliminary results

O'Shaughnessy, S. M. *et al. Applied Energy*, 2013, 102, 374–385.

The World Health Organization estimates that over 20% of the global population (~1.4 billion people) lack access to electricity. Furthermore, 40% of the global population (~2.7 billion people) rely on the traditional use of biomass for cooking. This study details the development of a prototype electrical generator for portable stoves commonly in use in the developing world. This generator is capable of delivering small amounts of off-grid electricity. Power is generated using the thermoelectric effect. A single thermoelectric module is utilized to convert a small portion of heat from the stove to electricity. The electricity produced is used to charge a single 3.3 V lithium–iron phosphate battery and drive a low power fan, as well as some other auxiliary features. The airflow produced by the fan is used in conjunction with a commercially available heat pipe heat sink to maintain an adequate temperature difference across the thermoelectric module. From experiments in the laboratory, a maximum thermoelectric generator power output of 5.9 W has been obtained. On average, 3 W h of energy was stored in a battery during a typical 1 h long burn. Three 1 h long burns produced sufficient energy to fully charge the battery. The performance of the electricity generating cooking stove has subsequently been tested in Malawi using locally sourced fuel and fire stoking methods.

13/03318 Stochastic weight trade-off particle swarm optimization for nonconvex economic dispatch

Chalermchaiarbha, S. and Ongsakul, W. *Energy Conversion and Management*, 2013, 70, 66–75.

This paper proposes a stochastic weight trade-off particle swarm optimization (SWT_PSO) for solving non-convex economic dispatch. The proposed SWT_PSO preserves the balance between global exploration and local exploitation to improve the algorithm search capabilities. The balance is retained through trading off stochastic weights among previous velocity momentum, cognitive and social components together with using dynamic acceleration coefficients trade-off. The mechanisms for increasing diversity of swarm members are also incorporated to avoid premature convergence. In addition, the novel stochastic trade-off momentum control factor is exploited to enhance the capability of refining quality of a candidate solution during the late search process. The proposed SWT_PSO is tested on four economic dispatch test systems. Test results demonstrate that the proposed approach yields better solution quality than the best reported results in the literature for all test systems.

13/03319 Techno-economic analysis of an optimized photovoltaic and diesel generator hybrid power system for remote houses in a tropical climate

Ismail, M. S. *et al. Energy Conversion and Management*, 2013, 69, 163–173.

A techno-economic analysis and the design of a complete hybrid system, consisting of photovoltaic (PV) panels, a battery system and a diesel generator as a backup power source for a typical Malaysian village household is presented in this paper. The specifications of the different components constructing the hybrid system were also determined. A scenario depending on a standalone PV and other scenario depending on a diesel generator only were also analysed. A simulation program was developed to simulate the operation of these different scenarios. The scenario that achieves the minimum cost while meeting the load requirement was selected. The optimal tilt angle of the PV panels in order to increase the generated energy was obtained using genetic algorithm. In addition, sensitivity analysis was undertaken to evaluate the effect of change of some parameters on the cost of energy. The results indicated that the optimal scenario is the one that consists of a combination of the PV panels, battery bank and a diesel generator. Powering a rural house using this hybrid system is advantageous as it decreases operating cost, increases efficiencies, and reduces pollutant emissions.

13/03320 The political economy of electricity dispatch reform in China

Kahrl, F. *et al. Energy Policy*, 2013, 53, 361–369.

The transition to a cleaner and more cost-efficient electricity system in China is political-economic as well as technological. An example is the reform of China's method of dispatching power plants, which potentially affects the economic relationships between consumers and producers, between grid and generating companies, and between central and provincial governments. Historically, coal-fired power plants in China all received roughly the same number of operating hours, regardless of efficiency or cost. In 2007, Chinese government agencies began to pilot 'energy efficient dispatch' which requires that generators be dispatched on the basis of thermal efficiency. Using a case study of Guangxi Zhuang Autonomous Region in southern China, the authors evaluated potential energy and cost savings from a change to energy efficient dispatch. It was found that the savings are at best relatively small, because large, efficient generators already account for a significant share of total generation. Moreover, as an administrative policy that does not change economic incentives, energy efficient dispatch exacerbates imbalances and centre-provincial tensions in the current system. The authors argue that incentive-based dispatch reform is likely to produce better outcomes, and that the keys to this reform are empowering an independent regulator with pricing authority and establishing a formal, transparent ratemaking process.

13/03321 Thermoeconomic optimization of three trigeneration systems using organic Rankine cycles: part I – formulations

Al-Sulaiman, F. A. *et al. Energy Conversion and Management*, 2013, 69, 199–208.

This part of the study presents the thermoeconomic optimization formulations of three new trigeneration systems using organic Rankine cycle: SOFC-trigeneration, biomass-trigeneration, and solar-trigeneration systems. A thermoeconomic modelling is employed using the specific exergy costing method while the optimization performed using the Powell's method to minimize the product cost of trigeneration (combined, cooling, heating, and power). The results help in understanding how to apply the thermoeconomic modelling and thermoeconomic optimization to a trigeneration system.

13/03322 Thermoeconomic optimization of three trigeneration systems using organic Rankine cycles: part II – applications

Al-Sulaiman, F. A. *et al. Energy Conversion and Management*, 2013, 69, 209–216.

In this part of the study, three new trigeneration systems are examined. These systems are SOFC-trigeneration, biomass-trigeneration, and solar-trigeneration systems. This study reveals that the maximum trigeneration-exergy efficiencies are about 38% for the SOFC-trigeneration system, 28% for the biomass-trigeneration system and 18% for the solar-trigeneration system. Moreover, the maximum cost per exergy unit for the SOFC-trigeneration system is approximately $38/GJ, for the biomass-trigeneration system is $26/GJ, and for the solar-trigeneration system is $24/GJ. This study reveals that the solar-trigeneration system offers the best thermoeconomic performance among the three systems. This is because the solar-trigeneration system has the lowest cost per exergy unit. Furthermore, the solar-trigeneration system has zero CO_2 emissions and it is based on a free renewable energy source.

13/03323 Transient efficiency measurement of a combined heat and power fuel cell generator

Hwang, J.-J. *Journal of Power Sources*, 2013, 223, 325–335.

The objective of the present paper is to conduct an experimental work to measure transient thermal/electrical efficiencies in a combined heat and power (CHP) fuel cell generator. An original-designed fuel cell CHP generator comprising a proton exchange membrane (PEM) fuel cell system, a power conditioning system, and a thermal recovery system is constructed. The thermal recovery system recaptures the thermal energy dissipated by the fuel cell stack, while the power conditioning system distributes the electrical power of the fuel cell system. Performance matrices including stack electrical efficiency, system electrical efficiency, thermal efficiency, and CHP efficiency are presented. Particular attention is placed on the variation of transient system efficiencies as the load is changed drastically. The time-averaged system efficiency is then concluded from the statistics of the transient system efficiency. Results show that the time-averaged efficiencies in electrical, thermal and CHP are about 37%, 24% and 61%, respectively, under 55% electrical power capacity of the generator. The instantaneous CHP efficiency could reach as high as 85% in the loading period.

Economics, policy, supplies, forecasts

13/03324 A new cascade NN based method to short-term load forecast in deregulated electricity market

Kouhi, S. and Keynia, F. *Energy Conversion and Management*, 2013, 71, 76–83.

Short-term load forecasting (STLF) is a major discussion in efficient operation of power systems. The electricity load is a non-linear signal with time dependent behaviour. The area of electricity load forecasting has still essential need for more accurate and stable load forecast algorithm. To improve the accuracy of prediction, a new hybrid forecast strategy based on cascaded neural network is proposed for STLF. This method is consists of wavelet transform, an intelligent two-stage feature selection, and cascaded neural network. The feature selection is used to remove the irrelevant and redundant inputs. The forecast engine is composed of three cascaded neural network (CNN) structure. This cascaded structure can be efficiently extract input/output mapping function of the non-linear electricity load data. Adjustable parameters of the intelligent feature selection and CNN is fine-tuned by a kind of cross-validation technique. The proposed STLF is tested on PJM and New York electricity markets. It is concluded from the results that the proposed algorithm is a robust forecasting method.

13/03325 A novel multi-zone reactive power market settlement model: a pareto-optimization approach

Saraswat, A. *et al. Energy*, 2013, 51, 85–100.

This paper presents a pareto-optimization based zonal day-ahead reactive power market settlement model named as multi-zone DA-RPMS model. Three competing objective functions such as total payment function (TPF) for reactive power support services from generators/synchronous condensers, total real transmission loss (TRTL) and voltage stability enhancement index (VSEI) are optimized simultaneously by satisfying various power system operating constraints while settling the day-ahead reactive power market. The proposed multi-zone DA-RPMS model is tested and compared with single-zone DA-RPMS model on standard IEEE 24-bus reliability test system. A hybrid fuzzy multi-objective evolutionary algorithm (HFMOEA) approach is applied and compared with NSGA-II for solving these DA-RPMS models in competitive electricity market environment. Further, both the single-zone and multi-zone DA-RPMS models are also analysed on the basis of market power owned by any generator/any generating company. The simulation results obtained confirm the superiority of HFMOEA in finding the better pareto-optimal fronts in order to take better day-ahead reactive power market settlement decisions.

13/03326 A queue-based interval-fuzzy programming approach for electric-power systems planning

Zhao, F. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 337–350.

In this study, a queue-based interval-fuzzy electric-power system (QIF-ESP) model is developed through coupling fuzzy queue (FQ) theory with interval-parameter programming (IPP). QIF-ESP cannot only handle uncertainties that are presented in terms of fuzzy sets and interval numbers, but also reflect the effects of fuzzy queue on energy resources allocation and system cost. The QIF-EPS model is applied to a case study of planning a regional-scale electric-power system, where two FM/FM/1 (fuzzy exponential inter-arrival time, fuzzy exponential service time, and one server) queues are incorporated within the modelling framework. Interval solutions with fuzzy arrival and service rates have been generated, which result in different energy resources allocation patterns as well as changed waiting costs and system costs. Compared with the conventional optimization methods, the QIF-ESP model can effectively handle queue problems and multiple uncertainties exist in energy-related processes and activities. Moreover, consideration of queuing problem impacts in the optimization model can provide more useful information for decision makers and gain in-depth insights into the effects of queuing problems for electric-power systems under multiple uncertainties.

13/03327 A regional model for sustainable biogas electricity production: a case study from a Finnish province

Huopana, T. *et al. Applied Energy*, 2013, 102, 676–686.

A regional model for sustainable biogas electricity production was formulated and tested for the Finnish province of North-Savo. By using the model, the aim was to support decision making for reducing greenhouse gas (GHG) emissions and increasing renewable energy production in the studied region in the biogas electricity production system. The system boundary of the model included transportation of waste, biogas production, heat and electricity production, as well as the delivery of heat and digestate to the end users. When electricity production was maximized in the studied region, the electricity production and GHG emissions were 20 GW h/year and 24 kt/year of CO_2 equivalent, respectively. When GHG emissions were minimized, the electricity production and GHG emissions were 20 GW h/year and 23 kt/year of CO_2 equivalent, respectively. By producing electricity of 20 GW h/year, the maximum GHG reductions were roughly 74% of the theoretical maximum GHG emissions of 90 kt/year of CO_2 equivalent in both cases. The regional electricity production potential of 20 GW h/year was only 21% of the maximum electricity production potential of 94 GW h/year. The locations of biogas plants, regional relative GHG emissions, potential feedstocks and regional electricity production were optimized in both cases in the studied region.

13/03328 A simulated rebounding algorithm applied to the multi-stage security-constrained transmission expansion planning in power systems

Hinojosa, V. H. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 168–180.

This research discusses the multi-stage security-constrained transmission network expansion planning. In modern power systems, the problem is formulated as a large-scale, mixed-integer, non-linear programming problem, which for a real power systems is very difficult to solve. Although remarkable advances have been made in optimization techniques, finding an optimal solution to a problem of this nature can still be extremely challenging. In this paper, a new constructive heuristic approach, based on a local controlled random search (simulated rebounding algorithm) is proposed to choose the decision variables. The model can produce better solutions than other references techniques such as particle swarm optimization, evolutionary particle swarm optimization, genetic algorithms, and simulated annealing algorithm, among other evolutionary methods. The methodology is applied to assess the capabilities of the proposed approach in the Ecuadorian and Chilean power systems as an example of application. Simulation results show that the proposed approach is accurate and very efficient, and it has the potential to be applied to real power system planning problems. The algorithm has been presented and applied to the multi-stage security-constrained transmission expansion planning.

13/03329 Adaptability of optimized cogeneration systems to deal with financial changes occurring after the design period

Magnani, F. S. *et al. Energy and Buildings*, 2013, 58, 183–193.

Cogeneration systems are energy efficient but when changes occur to the original design they can seem financially risky. Decreases in demand and increases in fuel prices can turn an optimal design into a failure, but that does not always have to be the case. This paper illustrates that cogeneration systems can be very robust to changes. A general cogeneration system is proposed consisting of one engine, three types of boilers and two types of chillers. This general system can use fuel or electricity as energy sources, as well as produce steam, chilled water and electricity for a commercial building. The objective function takes into account the initial investment and the operational life costs. Once the base case is optimized to the design parameters, the study proceeds with a series of case studies investigating the range of variations the system can support and continue to be the optimum. The major conclusions are the cogeneration system can stand an increase of up to 374% in the fuel tariff and an increase of up to 93% in the electricity tariff. Another conclusion is that cogeneration systems are robust in relation to variations in the fuel tariff in its second decade of operation.

13/03330 Asset maintenance planning in electric power distribution network using statistical analysis of outage data

Adoghe, A. U. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 424–435.

The problems faced by electric power utilities in developing countries today is that the power demand is increasing rapidly whereas the supply growth is constrained by aging generating and distributing assets, scarce resources for constructing new ones and other societal issues. This has resulted in the need for constructing new additional generating plants and a more economic ways of planning and maintaining existing generating and electric power distribution assets. System planning and maintenance that is based on reliability centred asset management approach had been adopted in this paper. Maintenance of critical asset is an essential part of asset management in distribution network. In most electric utilities, planning for maintenance constitutes an essential parts of asset management. The study concluded that it is beneficial to base asset maintenance management decisions on processed, analysed and tested outage data.

13/03331 Comparison of Sen transformer and UPFC for congestion management in hybrid electricity markets

Kumar, A. and Sekhar, C. *International Journal of Electrical Power & Energy Systems*, 2013, 47, 295–304.

Congestion management (CM) is one of the most important and challenging tasks of the independent system operator (ISO) in the deregulated environment. Recently, Sen transformer (ST) has emerged as an important power flow control device which has the capability of power flow control over a wide range like UPFC. This device with a conventional transformer and tap changers has the capability of bidirectional control of active and reactive power and can play a very important role in future markets for mitigating the congestion problems. In this paper, the capability of ST has been utilized to manage transmission line congestion for hybrid based electricity market model. The main contribution of the paper is: (i) to develop an optimal rescheduling of generators strategy for real time congestion management and impact of ST for congestion management, (ii) the comparison of ST with unified power flow controller (UPFC) for congestion management, (iii) the secure bilateral transactions determination in a hybrid market model and congestion management with both power flow controllers in combined pool and bilateral market model. The optimal location of ST and UPFC has been obtained solving mixed integer non-linear programming model of congestion management. The proposed model has been applied for results on IEEE 24-bus RTS test system.

13/03332 Components sizing of hybrid energy systems via the optimization of power dispatch simulations

Zhang, X. *et al. Energy*, 2013, 52, 165–172.

A hybrid energy system comprising the diesel generator, photovoltaic panels and battery bank is well suited for installation as a decentralized power generation system for the electrification of remote rural households in the developing countries. This paper proposes a new methodology for the components sizing of hybrid energy system based on the optimization of the power dispatch simulations. The optimization of the power dispatch with the operation of hybrid system is implemented by minimizing the cost of energy (COE) with consideration to the capital depreciation cost, fuel cost, emissions damage cost and maintenance cost. A hybrid system applicable to Alaminos, Philippines was studied using the proposed methodology. The simulation results show that the proposed sizing search method can lead to the convergence of the optimal objective solutions with reduction to its computational load. Two sizing solutions for the hybrid energy system are presented. The optimized power dispatch schedules and cost compositions of COE are analysed in detail.

13/03333 Customer value of smart metering: explorative evidence from a choice-based conjoint study in Switzerland

Kaufmann, S. *et al. Energy Policy*, 2013, 53, 229–239.

Implementing smart metering is an important field for energy policy to successfully meet energy efficiency targets. From an integrated social acceptance and customer-perceived value theory perspective, the authors model the importance of customer value of smart metering in this regard. They further shape the model on a choice-based conjoint experiment with Swiss private electricity customers. The study finds that overall customers perceive a positive value from smart metering and are willing to pay for it. Further, based on a cluster analysis of customers' value perceptions, four customer segments are identified, each with a distinct value perception profile for smart metering. It was found that energy policy and management should integrate a solid understanding of customer value for smart metering in their initiatives and consider different smart metering market segments within their measures.

13/03334 Economic analysis and optimal energy management models for microgrid systems: a case study in Taiwan

Chen, Y.-H. *et al. Applied Energy*, 2013, 103, 145–154.

The purpose of this research is to perform economic analysis, formulate an optimization model, and determine optimal operating strategies for smart microgrid systems. Microgrid systems are electricity supply systems that integrate distributed renewable energy production for local demand. Microgrids are able to reduce transmission losses and improve utilization efficiency of electricity and heat. Further, greenhouse gas emissions are reduced by utilizing an efficient power generation microgrid system. This study presents an energy management model that is used to determine optimal operating strategies with maximum profit for a microgrid system in Taiwan. The smart microgrid system is equipped with energy storage devices, photovoltaic power, and wind power generation systems. Sensitivity analyses of investment in storage capacity and growth in electricity demand are conducted for the smart microgrid model. The results show that appropriate battery capacity should be determined on the basis of both battery efficiency and power supply.

13/03335 Electricity purchase agreements and distributed energy policies for anaerobic digesters

Binkley, D. *et al. Energy Policy*, 2013, 53, 341–352.

Anaerobic digestion is increasingly recognized for its ability to produce renewable energy and reduce greenhouse gas emissions from livestock operations. In 2010, there were 2645 US dairy farms with herd sizes large enough to support anaerobic digesters, yet only 156 systems were in operation. This study analyses the net present value of digester systems under alternative electricity purchase agreements and how returns are affected by standby charges, net metering policies and the use of feed-in-tariffs. In order for digester potential to be fully realized on a state or national level, changes to distributed energy policy are required. Results indicated that standby charges can reduce revenues from offsetting electricity by an average of nearly 20%. Net metering rules limit participation among larger farms and negatively affect profitability by restricting engine–generator size. Lastly, the effectiveness of a fixed price feed-in-tariff policy for digesters is significantly affected by project size differentiation. Digester energy policies are similar nationwide, making this study useful for government regulatory agencies and digester owners throughout the USA.

13/03336 Energy intensities, EROIs (energy returned on invested), and energy payback times of electricity generating power plants

Weißbach, D. *et al. Energy*, 2013, 52, 210–221.

The energy returned on invested (EROI), has been evaluated for typical power plants representing wind energy, photovoltaics, solar thermal, hydro, natural gas, biogas, coal and nuclear power. The strict exergy concept with no ‘primary energy weighting’, updated material databases, and updated technical procedures make it possible to directly compare the overall efficiency of those power plants on a uniform mathematical and physical basis. Pump storage systems, needed for solar and wind energy, have been included in the EROI so that the efficiency can be compared with an ‘unbuffered’ scenario. The results show that nuclear, hydro, coal, and natural gas power systems (in this order) are one order of magnitude more effective than photovoltaics and wind power.

13/03337 Estimating the cost of improving quality in electricity distribution: a parametric distance function approach

Coelli, T. J. *et al. Energy Policy*, 2013, 53, 287–297.

The quality of electricity distribution is being more and more scrutinized by regulatory authorities, with explicit reward and penalty schemes based on quality targets having been introduced in many countries. It is then of prime importance to know the cost of improving the quality for a distribution system operator. This paper focused on one dimension of quality, the continuity of supply and estimated the cost of preventing power outages. For that, the authors made use of the parametric distance function approach, assuming that outages enter in the firm production set as an input, an imperfect substitute for maintenance activities and capital investment. This allowed identification of the sources of technical inefficiency and the underlying trade-off faced by operators between quality and other inputs and costs. For this purpose, panel data on 92 electricity distribution units operated by ERDF (Electricité de France – Réseau Distribution) in the 2003–2005 financial years was used. Assuming a multi-output multi-input translog technology, the authors estimate that the cost of preventing one interruption is equal to €10.7 for an average DSO. Furthermore, as expected, marginal quality improvements tend to be more expensive as quality itself improves.

13/03338 Estimation of electrical power consumption in subway station design by intelligent approach

Leung, P. C. M. and Lee, E. W. M. *Applied Energy*, 2013, 101, 634–643.

According to the records of the Hong Kong rail operator, MTR Corporation, the weekly electrical consumption of each railway station ranges from 18 to 230 MWh. Since the electrical consumption of stations is a major factor in the planning of infrastructure, a good prediction of the electrical consumption will greatly assist in the design of the station infrastructure. This study develops an intelligent approach to predict the energy consumption of railway stations. Multi-layered perceptron (MLP) is adopted to mimic the non-linear correlation between energy consumption, the spatial design of the station, meteorological factors and also the usage of the 19 stations selected. Coefficient of correlation is obtained between the MLP predicted results and the actual collected data to evaluate the performance of the prediction. A statistical approach was applied to assess the performance of the developed MLP model. It shows that minimum coefficient of correlation is 0.96 with a 95% confidence level, which is considered sufficient for engineering application. This approach is also adopted to predict the profile of the weekly electrical consumption of a selected station. The predicted profile reasonably agrees with that of the actual consumption. This study develops a useful tool to estimate the electrical power consumption of new MTR stations.

13/03339 Evaluating the supply security of the future Spanish generating system

Delgado, F. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 243–254.

This paper explores the evolution of the Spanish power system vulnerability over the next two decades and its dependency on fossil fuel prices and CO_2 allowances costs. Also, the influence of different generation technologies (clean coal, nuclear and solar technologies) on this vulnerability has been considered. The diversity of primary energy resources has been evaluated to carry out the above analysis by means of two indexes: the Shannon index (H) and an adapted biodiversity index (Δ). These indexes have been applied to the power results of the period 2013–2032 that are obtained from a stochastic linear model of the Spanish generating system. As a main conclusion, the vulnerability calculated with Δ is bigger than that deduced from H and showing a negative trend throughout the period. In order to reverse this tendency, the future Spanish generating system should be composed of all the available technologies, considering all the primary energy resources.

13/03340 Extreme daily increases in peak electricity demand: tail-quantile estimation

Sigauke, C. *et al. Energy Policy*, 2013, 53, 90–96.

A generalized pareto distribution (GPD) is used to model extreme daily increases in peak electricity demand. The model is fitted to years 2000–2011 recorded data for South Africa to make a comparative analysis with the generalized pareto-type (GP-type) distribution. Peak electricity demand is influenced by the tails of probability distributions as well as by means or averages. At times there is a need to depart from the average thinking and exploit information provided by the extremes (tails). Empirical results show that both the GP-type and the GPD are a good fit to the data. One of the main advantages of the GP-type is the estimation of only one parameter. Modelling of extreme daily increases in peak electricity demand helps in quantifying the amount of electricity which can be shifted from the grid to off peak periods. One of the policy implications derived from this study is the need for day-time use of electricity billing system similar to the one used in the cellular telephone/and fixed line-billing technology. This will result in the shifting of electricity demand on the grid to off peak time slots as users try to avoid high peak hour charges.

13/03341 High performance computing for detection of electricity theft

Depuru, S. S. S. R. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 21–30.

Transmission and distribution of electricity involve technical as well as non-technical losses (NTLs). Illegal consumption of electricity constitutes a major portion of the NTL at distribution feeder level. Considering the severity and devastating effects of the problem, illegal consumption of electricity has to be detected instantly in real-time. To this end, this paper investigates the possibility and role of high-performance computing algorithms in detection of illegal consumers. This paper designs and implements an encoding procedure to simplify and modify customer energy consumption data for quicker analysis without compromising the quality or uniqueness of the data. This paper parallelizes overall customer classification process. The parallelized algorithms have resulted in appreciable results as displayed in the results section of the paper.

13/03342 Identifying spikes and seasonal components in electricity spot price data: a guide to robust modeling

Janczura, J. *et al. Energy Economics*, 2013, 38, 96–110.

An important issue in fitting stochastic models to electricity spot prices is the estimation of a component to deal with trends and seasonality in the data. Unfortunately, estimation routines for the long-term and short-term seasonal pattern are usually quite sensitive to extreme observations, known as electricity price spikes. Improved robustness of the model can be achieved by (a) filtering the data with some reasonable procedure for outlier detection, and then (b) using estimation and testing procedures on the filtered data. This paper examines the effects of different treatments of extreme observations on model estimation and on determining the number of spikes (outliers). In particular they authors compare results for the estimation of the seasonal and stochastic components of electricity spot prices using either the original or filtered data. They find significant evidence for a superior estimation of both the seasonal short-term and long-term components when the data have been treated carefully for outliers. Overall, the findings point out the substantial impact the treatment of extreme observations may have on these issues and, therefore, also on the pricing of electricity derivatives like futures and option contracts. An added value of this study is the ranking of different filtering techniques used in the energy economics literature, suggesting which methods could be and which should not be used for spike identification.

13/03343 Impact of climate change on Taiwanese power market determined using linear complementarity model

Tung, C.-P. *et al. Applied Energy*, 2013, 102, 432–439.

The increase in the greenhouse gas concentration in the atmosphere causes significant changes in climate patterns. In turn, this climate change affects the environment, ecology, and human behaviour. The emission of greenhouse gases from the power industry has been analysed in many studies. However, the impact of climate change on the electricity market has received less attention. Hence, the purpose of this research is to determine the impact of climate change on the electricity market, and a case study involving the Taiwanese power market is conducted. First, the impact of climate change on temperature is estimated. Next, because electricity demand can be expressed as a function of temperature, the temperature elasticity of demand is measured. Then, a linear complementarity model is formulated to simulate the Taiwanese power market and climate change scenarios are discussed. Therefore, this paper establishes a simulation framework for calculating the impact of climate change on electricity demand change. In addition, the impact of climate change on the Taiwanese market is examined and presented.

13/03344 Impacts of electric vehicle charging under electricity market operations

Foley, A. *et al. Applied Energy*, 2013, 101, 93–102.

The Irish government set a target in 2008 that 10% of all vehicles in the transport fleet should be powered by electricity by 2020. Similar electric vehicle targets have been introduced in other countries. In this study, the effects of 213,561 electric vehicles on the operation of the single wholesale electricity market for the Republic of Ireland and Northern Ireland is investigated. A model of Ireland's electricity market in 2020 is developed using the power systems market model called PLEXOS for power systems. The amount of CO_2 emissions associated with charging the electric vehicles and the impacts with respect to Ireland's target for renewable energy in transport is also quantified. A single generation portfolio and two different charging scenarios, arising from a peak and off-peak charging profile are considered. Results from the study confirm that off-peak charging is more beneficial than peak charging and that charging electric vehicles will contribute 1.45% energy supply to the 10% renewable energy in transport target. The net CO_2 reductions are 147 and 210 kt CO_2, respectively.

13/03345 Inducing low-carbon investment in the electric power industry through a price floor for emissions trading

Brauneis, A. *et al. Energy Policy*, 2013, 53, 190–204.

Uncertainty about long-term climate policy is a major driving force in the evolution of the carbon market price. Since this price enters the investment decision process of regulated firms, this uncertainty increases the cost of capital for investors and might deter investments into new technologies at the company level. The authors apply a real options-based approach to assess the impact of climate change policy in the form of a constant or growing price floor on investment decisions of a single firm in a competitive environment. This firm has the opportunity to switch from a high-carbon 'dirty' technology to a low-carbon 'clean' technology. Using Monte Carlo simulation and dynamic programming techniques for real data, the optimal CO_2 price floor level and growth rate is determined in order to induce investments into the low-carbon technology. It was found that a carbon price floor can be used to induce earlier low-carbon technology investment and show this result to be robust to a large variety of input parameter settings.

13/03346 Not locked-in? The overlooked impact of new gas-fired generation investment on long-term decarbonisation in the UK

Chignell, S. and Gross, R. J. K. *Energy Policy*, 2013, 52, 699–705.

This paper contrasts the potential increase in gas-fired power generation in the UK in the period to 2020 with the ambitious decarbonization goals set forth for this sector. An increase in combined cycle gas turbine (CCGT) capacity, in particular, only represents a threat to long-term decarbonization if some 'lock-in' exists. It is against this background, and in the interest of challenging the perception of no significant lock-in to gas-fired generation, that this paper identifies investment lock-in as phenomenon of relevance to policy-makers. The paper determines both direct and indirect ways in which investment in significant new CCGT capacity could negatively impact on the likelihood of meeting decarbonization goals through 'locking-in' the existing technological system. It also identifies that the technical lifetime, and not just the capital repayment period, of CCGT assets is relevant in understanding the strength of the lock-in. Finally, a regulatory structure that aligns with the long-term targets in place is identified as providing a clear signal for investors and asset owners that may reduce the risk of 'investment lock-in'.

13/03347 Outage data analysis of utility power transformers based on outage reports during 2002–2009

Abdelfatah, M. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 41–51.

Statistical analysis of failures and forced outages of power transformers constitute an important basis for asset management of these transformers. Results of the statistical analysis can be used, for example, to enhance utility reliability, influence transformer design and technology, and improve maintenance and condition monitoring practices. In addition, various methods for transformer reliability evaluation require that the expected values of component outage rates, outage durations, and repair durations be known. In this paper, outage data are obtained from the Egyptian Electricity Transmission Company (EETC). This work presents outage data analysis over 8 years, from 2002 to 2009, for 1922 (average number) transformers in voltage populations ranging from 33 kV to 500 kV and MVA rating from 5 to 500 MVA. Forced outages due to correct and false action of transformer's protection systems are carefully considered. Outage data analysis is conducted according to two basic phases. In the first phase, failure and repair analysis of transformers is performed while in the second phase impact of transformer outages on customers is assessed. Percentage average number of failures (*%AANF*) and annual average repair time (*AART*) per transformer are used to represent the failure and repair data of power transformers. Two indicators are used to represent the impact of transformer outages on customer interruptions. These indicators are the annual average interrupted MW (*AAIMW*) and annual average customer-interruption duration (*AACID*). A summary of the main outcomes of the work presented in this paper is provided in the conclusions' section; however, it is worthy to be mentioned here that the fire-fighting systems are responsible for the highest number of false trips in all voltage subpopulations except the 220 kV subpopulation where the dominant cause of false trips is the busbar protection. Therefore, it is recommended to improve the maintenance and design of this protection equipment to reduce the failure rate of power transformers.

13/03348 Profitability and productivity changes in the Korean electricity industry

Hwang, W.-S. and Lee, J.-D. *Energy Policy*, 2013, 52, 531–542.

The Korean electricity industry saw significant changes following the reform in April 2001. Until the past decade, the industry was monopolized by the Korea Electric Power Corporation (KEPCO), a state-owned, vertically integrated company. The 2001 reform divided KEPCO's power generation division into six power generation companies, with the aim of improving efficiency and introducing competition in the electricity industry. This study used capital total factor productivity to analyse profit changes from fixed input capital, and an index number profit decomposition to examine the sources of the profit changes. The authors investigated the industry thoroughly from three points of view: the overall industry over time; the power generation sector by company; and the transmission and distribution sectors of the KEPCO. Next, the authors measured how the profits from productivity growth were distributed to consumers, fuel suppliers, employees, and company owners. The results suggest that a more reasonable price system for both wholesale and consumer prices needs to be implemented prior to the privatization and deregulation of the Korean electricity industry.

13/03349 Strategic planning in the electricity generation sector through the development of an integrated Delphi-based multi-criteria evaluation model

Kaldellis, J. K. *et al. Fuel*, 2013, 106, 212–218.

Decision making process in selecting the most suitable technological solutions for electricity power generation in terms of strategic planning comprises a rather complex procedure with several contradicting factors involved. In this context, development of an appropriate evaluation methodology that will provide decision makers with a useful tool is the aim of the specific study. To achieve this, the Delphi method is used in order to compare a number of alternative technologies with respect to several characteristics, e.g. cost, environmental impacts, social impacts and technological status. According to this method, a properly formed questionnaire is sent to a number of experts, currently related to the power generation sector. After the evaluation of results, weight factors are determined, so that the different technologies can be ranked according to both their scoring in each criterion category and their global scoring, independently of categories, on the basis of a multi-criteria analysis. Emphasis is currently given on the electricity generation sector of Greece, with application of the developed methodology carried out for Crete, i.e. the biggest Greek island.

13/03350 Whatever the customer wants, the customer gets? Exploring the gap between consumer preferences and default electricity products in Germany

Kaenzig, J. *et al. Energy Policy*, 2013, 53, 311–322.

In liberalized electricity markets, residential customers can choose their preferred provider and select among a variety of different electricity products, including green power options. Successful product design and marketing strategies for green electricity may provide electricity providers with a competitive advantage, while at the same time contributing to energy policy objectives. This requires, however, a thorough understanding of customer preferences. This study investigated the relative importance of different product attributes in creating customer value, and found that price and electricity mix are the two most important attributes. The German electricity customers surveyed as part of this study in 2009 expressed an implicit willingness to pay a premium of about 16% for electricity from renewable sources. It was concluded that consumers are willing to pay a significant price premium for an upgrade from the current default electricity mix in Germany to a more environmentally friendly default electricity mix, and discuss implications for marketing strategy and energy policy. These findings are based on a dataset of 4968 experimental choices made by 414 German residential consumers, collected in a stated preference survey.

07 STEAM RAISING

Boiler operation/design

13/03351 Behaviour of steam generator bolted flange joints at elevated temperatures

Vinod, V. *et al. Annals of Nuclear Energy*, 2013, 51, 307–310.

Manholes with flanged joints are provided in the sodium heated once through straight tube steam generators of prototype fast breeder reactors. The material of construction of the steam generator is modified 9Cr 1Mo grade steel with studs made of 1Cr 0.5Mo steel. During the commissioning of model steam generator, the flanged joint lost its leak tightness at elevated temperature due to differential thermal expansion between flange and stud. A design modification incorporating sleeves of higher thermal expansion coefficient is discussed in this paper.

13/03352 Cost effective design of compound parabolic collector for steam generation

Gudekar, A. S. *et al. Solar Energy*, 2013, 90, 43–50.

This study presents a working model of a compound parabolic collector (CPC) system for the application of process steam generation. It is easy for fabrication, operation and has a lower cost compared to other available concentrating solar collector systems with further possibility of lowering the cost. An experimental demonstration unit having an aperture area of nearly 30 m^2 was set up and tested for steam generation. The performance analysis of the system shows potential of improving thermal efficiency up to 71%. By virtue of its geometry, the proposed CPC system requires much lesser mirror area compared to conventional CPC design and require single tilt adjustment per day for a daily 6 h operation.

13/03353 Modeling of ethane pyrolysis process: a study on effects of steam and carbon dioxide on ethylene and hydrogen productions

Yancheshmeh, M. S. S. *et al. Chemical Engineering Journal*, 2013, 215–216, 550–560.

In present work, ethylene and hydrogen production is investigated through thermal cracking of ethane in domestic petrochemical plant. In the thermal cracking process, a mixture of ethane and steam is introduced into radiant tubes located vertically in a furnace. The use of steam is mainly due to the partial removal of coke which has undesirable effects on the process. The coke deposition along the tubes causes high pressure drops and also reduction in production yield. In this study, the ethane thermal cracking process of this company is modelled and solved numerically. A comparison between model results and experimental data shows that the model can predict the process accurately. In addition, the effects of using carbon dioxide instead of steam are investigated on coke deposition. According to the results of two cases, the thermal cracking process in presence of CO_2 is superior to the conventional process because of higher ethylene and hydrogen productions and less coke thickness. The simulation results reveal that the run length of the reactor in presence of CO_2 becomes as twice as the one in presence of steam.

13/03354 New investigation on diagnosing steam production systems from multivariate time series applied to thermal power plants

Blanco, J. M. *et al. Applied Energy*, 2013, 101, 589–599.

One of the main aspects in energy conversion systems is to identify which time segment of instrumental recorded measurements allows accurate characterization of the system operation mode under a so-called ‘quasi steady-state’. In this paper, a diagnosis procedure on an existing steam generator operating at base load in a reference power plant has been improved. The setting points for a group of key variables were considered as reference values. To assess the effects of further deviations during the time segments of operation, a set of reference variables estimated fuel overconsumption levels with regard to a theoretical zero deviation. The appropriate combination of the above-mentioned regulated outputs, together with a set of suggested key modules, allowed the careful building of variants of tailor-made enhanced developments for diagnosis proposals. Finally, the contribution of this study to the assessment of compliance with environmental regulations was achieved, showing relevant savings in terms of energy consumption.

13/03355 Numerical study of heat transfer enhancement in the receiver tube of direct steam generation with parabolic trough by inserting metal foams

Wang, P. *et al. Applied Energy*, 2013, 102, 449–460.

The present numerical simulation investigates the effect of inserting metal foams in receiver tube of parabolic trough collector on heat transfer. The effects of layout (top/bottom), geometrical parameter (H), and porosity (φ) of metal foams on the flow resistant, heat transfer and thermo-hydraulic performance are analysed. Optimum thermo-hydraulic performance considering the flow resistance increase is obtained when $H = 0.25$ (bottom), Nu increases about 5–10 times with the increase of f 10–20 times and the PEC range from 1.4 to 3.2. Optimum thermal performance is obtained when $H = 0.75$ (top), Nu increases about 10–12 times with the increase of f 400–700 times and the PEC range from 1.1 to 1.5. The maximum circumferential temperature difference on the out surface of receiver tube decreases about 45% which will greatly reduce the thermal stress. The result shows that for constant layout and φ, the H effects on the thermal performance greatly, but for constant layout and H, the φ effects on the thermal performance slightly. Moreover, the layout in view of no-uniform heat flux boundary affects the heat transfer significantly. These methods and results can be extended to the heat transfer enhancement of all the solar concentrated receivers.

13/03356 Online life estimation for steam turbine rotor

Sun, Y.-J. *et al. Journal of Loss Prevention in the Process Industries*, 2013, 26, (1), 272–279.

Finite element analysis could achieve a near perfect result in computing the temperature field and stress field of steam turbine rotor in operation. This paper adopts the input and output data of finite element analysis under cold start-up process to establish an online damage monitoring model of a steam turbine rotor. The sensitivity of thermal stress transfer function is analysed using Nyquist plot. Comparison between finite element analysis model and this proposed model validates the accuracy of this work in assessing the low cycle fatigue damage. The present paper introduces a feasible online damage-monitoring methodology of steam turbine rotor in engineering.

13/03357 Reduction mechanisms of ash deposition in coal and/or biomass combustion boilers

Naganuma, H. *et al. Fuel*, 2013, 106, 303–309.

Some ash particles in solid fuels adhere on heat exchanger tube surfaces inside coal and/or biomass combustion boilers. The authors have already proposed a surface treatment on tubes, using a thermal spraying technique, to reduce ash deposition. Understanding reduction mechanisms of the ash deposition is necessary to evaluate effects of the surface treatment technique on the reduction of ash deposition. The reduction mechanisms of the ash deposition were elucidated due to physical and chemical aspects, measuring adhesion forces between the ash particles and some alloy specimens of the tube at high temperature under the simulated boiler conditions. As a result, the adhesion force increased with time and depended on both the ash types and the alloy specimens. The thermal spraying of nickel alloy, in particular, could reduce the adhesion force. Moreover interface reactions between the ash particles and the alloy specimen played an effective role in increasing the adhesion force, alkali metal compounds in the ash samples also related to an increase of the adhesion force. Iron, which was one of the main alloy elements, diffused into the ash deposition layer beyond the interface. This observation result suggested that the interface reactions of the ash particles with the alloy caused an increase of the adhesion force.

13/03358 Smooth combustion of gaseous fuels in a novel configuration of fluidized bed

Okasha, F. *Fuel*, 2013, 106, 512–518.

A novel configuration has been developed and applied in burning gaseous fuels. It enables gaseous fuels to burn smoothly like a normal premixed flame avoiding acoustic effect acoustic effects and explosions due to volume combustion in bubble phase. A gaseous fuel partially premixed with air is fed through a jet pipe to be issued vertically upward in the upper part of the bed. The jet is able to establish a permanent fountain of particles in the freeboard. The remaining part of air is fed through the distributor to fluidize bed solids. Applying the proposed configuration confirms a rapid reliable method for initial heating of fluidized bed combustor. The experiments demonstrate that the bed temperature attains 800 °C within about 10 min. The normal acoustic effects and bubbles explosion due to volume combustion were not recognized. Temperature distribution has been measured in axial and radial directions. The obtained results indicate that applying the novel configuration dampens greatly the overheating in freeboard, in particular, at lower bed temperatures. The particles of created fountain absorb a great part of the heat released in freeboard and recover it back to the bed. Staged air combustion technique has been also applied using the novel configuration. Propane premixed with air is fed through the distribution while the remaining part of air is fed through the jet pipe to create a fountain. The obtained results demonstrate that the freeboard temperature rise is also greatly reduced. The power consumption in delivering gases to the combustor is found much lower when applying the proposed configuration rather than feeding all gases through the gas distributor. Moreover, bubble sizes reduce considerably in the main bed as only a part of gases passes through the main bed.

08 COMBUSTION

Burners, combustion systems

13/03359 Co-effects of sulfur dioxide load and oxidation air on mercury re-emission in forced-oxidation limestone flue gas desulfurization wet scrubber

Cheng, C.-M. *et al. Fuel*, 2013, 106, 505–511.

Re-emission of Hg^0 refers to the reduction of oxidized mercury (Hg^{2+}) to the elemental mercury (Hg^0) in a wet flue gas desulfurization process (WFGD), resulting Hg^0 re-emits to the flue gas and increasing mercury emission for a coal combustion power plant. The correlations between re-emission of Hg^0 and operation parameters of WFGD process, i.e. sulfur dioxide removal, oxidation air flow, and pH of FGD slurry, were investigated with mercury field data collected from two coal combustion power plants (Plants C and O). At Units 31/32 of Plant C, coupling mercury results and the plant information (PI) data suggested that an increase of the oxidation air flow in the WFGD effectively inhibited the re-emission of Hg^0, and consequently increased the flue gas mercury removal efficiency from 63% to over 92%. But at Plant O, the increase of the oxidation air flow can sometimes increase Hg^0 re-emission. It was further found that the re-emission of Hg^0 at Plant O was strongly correlated not only to the flow rate of the oxidation air in the forced-oxidation operation conditions, but also to the amount of sulfur dioxide removed from the flue gas by the FGD scrubber (i.e. the sulfur dioxide load in the scrubber). Possible mechanisms were proposed.

13/03360 Combustion and heat transfer characteristics of oxy-coal combustion in a 100 MW_e front-wall-fired furnace

Park, S. *et al. Fuel*, 2013, 106, 718–729.

Oxy-coal combustion exhibits different characteristics of combustion, flow and heat transfer from those of air-coal combustion, due to the high concentration of CO_2 and H_2O in the product gases. Using computational modelling, this study investigated the combustion and wall heat flux (WHF) of a 100 MW_e boiler under air- and oxy-coal combustion conditions. The boiler had 12 swirl burners installed on the front wall for thermal input of 284 MW_{th}. Flame temperatures and corresponding WHF in oxy-coal combustion increased linearly as O_2 concentration increased from 24% to 30%. The case with 28% O_2 achieved the same level of WHF with that of air-coal combustion, which had a similar adiabatic flame temperature. Due to the lower heat capacity, the gas temperature above the burner region lowered more rapidly in air-coal combustion than in oxy-coal combustion. The proportion of char converted by CO_2 and H_2O increased from approximately 8% in air-coal combustion to 19–23% in oxy-coal combustion. The increased rates of endothermic gasification reactions by CO_2 and H_2O lowered the temperature in the internal recirculation zone during oxy-coal combustion. This retarded char oxidation upstream of the flames.

13/03361 Combustion chemical kinetics of biodiesel and related compounds (methyl and ethyl esters): experiments and modeling – advances and future refinements

Coniglio, L. *et al. Progress in Energy and Combustion Science*, 2013, 39, (4), 340–382.

The motivation for and challenges in reducing the world's dependence on crude oil while simultaneously improving engine performance through better fuel efficiency and reduced exhaust emissions have led to the emergence of new fuels and combustion devices. Over the past 10 years, considerable effort has gone into understanding combustion phenomena in relation to emerging fuel streams entering the market. The present article focuses specifically on one typical emerging transportation fuel dedicated to the diesel engine, biodiesel, with an emphasis on ethyl esters because of recently renewed interest in its use as a completely green biofuel. Based on a review of the research developments over the past 10 years in advanced experimental and kinetic modelling related to the oxidation of biodiesel and related components, the main gaps in the field are highlighted to facilitate the convergence toward clean and efficient combustion in diesel engines. After briefly outlining the synergy between 'feedstocks – conversion process – biodiesel combustion', the combustion kinetics of methyl and ethyl biodiesels are reviewed with emphasis on two complementary aspects: mechanism generation based on a detailed chemical kinetic approach that leads to predictive combustion models and experimental combustion devices that generate the data required during the development and validation of the predictive models.

13/03362 Computational study of crevice soot entrainment in a diesel engine

Tan, S. M. *et al. Applied Energy*, 2013, 102, 898–907.

In this study, operating parameters affecting spatial evolution of combustion soot and the associated transport processes into crevice region in a light-duty diesel engine were appraised. Numerical computation of diesel combustion was undertaken by means of linking a plug-in chemistry solver namely, CHEMKIN-CFD into ANSYS FLUENT 12, a commercial computational fluid dynamics (CFD) software. The mesh domain comprised the crevice region to allow quantitative and qualitative inspections of species entrained into the crevice. Effects on the soot spatial evolution and the soot entrainment into crevice and region near the cylinder liner are studied for different injection strategies. This includes single injection with different start of injection (SOI) timings, as well as two main injection pulses with different fuel mass distribution and dwell period in between the two. Soot entrainment process is found to occur through two phases, which is after the ignition process and at the end of the expansion stroke. Most significant soot mass entrainment is found in cases with retarded fuel injection and split-main injection with large separation in between the pulses. Advancing the SOI reduces the soot concentration in the combustion chamber and correspondingly moderates the soot entrainment process. Implementing a close-coupled injection has a more significant effect in reducing soot entrainment in the late injection cases as compared to those with advanced injection. Amount of soot near the cylinder liner for all cases are between 20 and 2000 times higher than those in the crevice region, and soot entrainment via mass transport is dominant as compared to the soot formation near the crevice. For future investigation, improvement can be made to the CFD submodels to account for the thermophoretic effect on soot deposition process.

13/03363 Conceptual models for partially premixed low-temperature diesel combustion

Musculus, M. P. B. *et al. Progress in Energy and Combustion Science*, 2013, 39, (2–3), 246–283.

Based on recent research within optically accessible engines and combustion chambers, conceptual models for low-temperature combustion (LTC) diesel engines are proposed. To provide a reference to which the LTC conceptual models may be compared, an established conceptual model framework for conventional diesel combustion is first reviewed and updated. Then, based on multiple optical diagnostic observations and homogeneous reactor simulations using detailed chemical kinetic mechanisms, extensions to the existing conceptual model are proposed. The LTC conceptual models are not intended to describe all LTC strategies, but rather a common subset of low-load, single-injection, partially premixed compression ignition conditions that are diluted by exhaust-gas recirculation to oxygen concentrations in the range of 10–15%. The models describe the spray formation, vaporization, mixing, ignition, and pollutant formation and destruction mechanisms that are consistent with experimental observations and modelling predictions for LTC diesel engines. Two separate subcategories are offered for either heavy-duty, large-bore or for light-duty, small-bore engines. Relative to the existing conventional diesel conceptual model, the features of the LTC conceptual models include longer liquid-fuel penetration, an extended ignition delay that allows more premixing of fuel, a more distinct and temporally extended two-stage ignition, more spatially uniform second-stage ignition, reduced and altered soot formation regions, and increased overmixing leading to incomplete combustion.

13/03364 Effects of blending hydrothermally treated municipal solid waste with coal on co-combustion characteristics in a lab-scale fluidized bed reactor

Jin, Y. *et al. Applied Energy*, 2013, 102, 563–570.

Experiments on co-combustion of municipal solid waste (MSW) and coal were conducted in a bubbling fluidized bed (BFB). The MSW sample was pretreated through hydrothermal treatment (HT) for obtaining uniform characteristics. MSW blending ratios as 10%, 20%, 30% and 50% were selected and tested at 700, 800, 900 °C to verify to which extent coal can be substituted with HT MSW in terms of emissions and unburnt carbon (UC) in fly ash (FA). The results obtained in this study showed that the lowest CO and NO emissions were found at 20% and 30% HT MSW blending respectively. Moreover, the SO_2 emissions decreased with the HT MSW addition and the HCl emissions were below 5 ppm. Furthermore, the UC contents decreased at the mixing ratio below 30% at low temperature. Positive synergistic relationships were identified and it is possible to accept 30% MSW combustion in a coal-fired BFB reactor.

13/03365 Experimental and numerical studies on the flame instabilities in porous media

Shi, J.-R. *et al. Fuel*, 2013, 106, 674–681.

Flame instabilities of inclination and breakup for lean CH_4/air combustion in porous media are studied experimentally and numerically. Inclination and breakup are observed in the quartz tube filled with alumina pellets of 3 mm in diameter for equivalence ratio range of 0.435–0.490. The effect of the equivalence ratio on the flame inclination and breakup are discussed and the results show that the equivalence ratio plays an important role on the breakup and flame inclination. Breakups always happen when the inclinational angle reaches 54–60°. In order to explain the motivities of the inclination, a two-dimensional one-step chemical reaction, two-temperature model without initial angles are carried out to simulate the experimental cases. In order to check the possible motivities of inclination, profiles (not uniform) were assumed of inlet velocity of premixed gas and equivalence ratio at inlet, different porosities in the tube, half the same on the right, half on the left, in the simulations. The results show that the inhomogeneous inlet velocity gives slight influence on the inclination, but the different distribution of porosity and the inhomogeneous equivalence ratio at inlet give great influences on the inclination. Calculation results show that the heat loss have a significant influence in determining the flame shape at the initial moment and lead to an increase in the development of the inclination instability. At a low mixture velocity, hydrodynamic effect on the inclination instability is ignored, while the inclination angle of the flame front continually increases as the mixture velocity increase.

13/03366 Experimental and theoretical study on the influence of temperature and humidity on the flammability limits of ethylene (R1150)

Wu, X. *et al. Energy*, 2013, 52, 185–191.

The lower flammable limit (LFL) and upper flammable limit (UFL) of R1150 were researched experimentally on a self-made test rig according to the Chinese National Standard GB/T12474 under variable temperature and humidity conditions. Results showed that the LFL increased with the decrease of temperature, while the UFL reduced, therefore the flammable range shrank 3.42% from 55 to −5 °C. Another group of experiments had been carried out to test the influence of humidity on the flammable limits of R1150 at 25 °C, which presented that the LFL increased less than 0.1 and UFL reduced 0.87 in volume fraction when humidifying the air to 42.4% (relative humidity). At the same time, a new method of estimating the LFLs of general hydrocarbons was presented and the relative deviation between the calculated value and experimental datum of R1150 was as small as 0.88%. On that basis, the influence of temperature on the LFL of R1150 was estimated by adding parameter enthalpy into the computational formula, the relative errors lay in 0.35–2.54% at the temperature range from −5 to 55 °C. The research achievements can benefit for utilizing the hydrocarbons refrigerants in variable temperature and relative humidity.

13/03367 Experiments and stochastic simulations of lignite coal during pyrolysis and gasification

Ahmed, I. I. and Gupta, A. K. *Applied Energy*, 2013, 102, 355–363.

Lignite pyrolysis and gasification has been conducted in a semi batch reactor at reactor temperatures of 800–950 °C in 50 °C intervals. CO_2 has been used as the gasifying agent for gasification experiments. The objective of this investigation is to understand the mechanism of syngas evolution during pyrolysis and to unravel the effect of CO_2 on pyrolysis mechanism. Stochastic simulations of lignite pyrolysis have been conducted using Gillespie algorithm. Two reaction mechanisms have been used in the simulations; first order, single step mechanism and the FLASHCHAIN mechanism. The first order single step mechanism was successful in fitting cumulative yield of CO_2, CO, CH_4 and other hydrocarbons (C_nH_m). The first order, single step failed to fit the cumulative yield of hydrogen, which suggests a more complex mechanism for hydrogen evolution. Evolution of CO_2, CO, CH_4, C_nH_m and H_2 flow rates has been monitored. The only effect of CO_2 on pyrolysis mechanism is promotion of reverse water gas shift reaction for the experiments described here. Methane evolution extended for slightly longer time than other hydrocarbons and hydrogen evolution extended for a slightly longer time than methane. This indicated the evolution of hydrogen via further pyrolysis of aliphatic hydrocarbon. It is also suggested that this step occurs in series after aliphatic hydrocarbons evolution by bridges scission.

13/03368 Extinction, discharge, and thrust characteristics of methanol fueled meso-scale thrust chamber

Shirsat, V. and Gupta, A. K. *Applied Energy*, 2013, 103, 375–392.

A meso-scale heat recirculating thrust chamber has been developed for use with methanol, by utilizing steam/oxygen as an oxidizer. The steam/oxygen mixture serves as a surrogate for hydrogen peroxide. The extinction regimes, discharge characteristics, and both steady state and pulsing thrust characteristics are presented. Differences between the extinction behaviour of the thrust chamber both without and with the nozzle were explored and a non-dimensional extinction criterion established to predict low *Re* extinction. The discharge characteristics: coefficient of discharge and characteristic velocity efficiency were determined and correlated to throat Reynolds number. Thrust measurements taken with the indirect method show reasonable agreement with the isentropic solution for the experimental stagnation conditions, suggesting high nozzle efficiency despite low chamber pressures and high gas temperatures. The behaviour of the thrust chamber in pulsed configuration was tested with methanol/oxygen and methanol/water/oxygen mixtures. High speed cinematography was used to study the evolution of the flame during the pulse.

13/03369 Grass pellet quality index: a tool to evaluate suitability of grass pellets for small scale combustion systems

Cherney, J. H. and Verma, V. K. *Applied Energy*, 2013, 103, 679–684.

The USA's renewable fuels policy strongly encourages biomass crop production, which should lead to expansion of biomass heating scenarios. Chemical composition of grass biomass can be extremely variable, depending on species, soil fertility, and harvest management. Biomass quality concerns have hindered the development of grass biomass for residential combustion, with no comprehensive evaluation system for grass pellet quality. Quality labelling will strengthen the fledgling grass biomass heating market, gain consumer confidence, and help to control combustion related emissions. The proposed system sums qualitatively different parameters into one quality index for relative evaluation and ranking of grass pellets for residential combustion potential. Parameters were selected and weighted for their relative importance based on available literature. Weighting was accomplished by adjusting the compositional working range for each parameter. A limit also was established for each parameter, beyond which the pellet lot was considered as unacceptable for residential combustion, regardless of the total quality index score. The model structure allows for effective evaluation and ranking of grass pellet lots regardless of the specific values ultimately chosen for acceptable limits and working ranges by the industry. Applying the quality index to a range of grass pellet types resulted in a reasonable ranking of pellets based on physical characteristics and composition.

13/03370 Kinetic effect of hydrogen addition on natural gas premixed flames

de Ferrières, S. *et al. Fuel*, 2013, 106, 88–97.

The chemical structure of laminar premixed natural gas flame with and without 60% of hydrogen on the fuel has been studied experimentally and numerically at atmospheric pressure. This work completes the recent results reported for low-pressure premixed flames. Both flames have been stabilized under similar conditions (similar cold velocity and C/O). Stable mole fraction profiles have been obtained by gas chromatography, FTIR and GC–MS. Temperature profiles have been measured by thermocouple and corrected from radiation losses. Comparatively to low pressure, more traces species have been observed at atmospheric pressure. These new results have been modelled and a revised version of GDF-Kin®3.0-NCN is reported. This version is able to predict the present data (mole fraction profiles and recent burning velocities of natural gas and natural gas/hydrogen flames) without alteration of previous predictions. Reactions path analysis confirms that hydrogen enhances H-abstraction reactions by H atoms under lean conditions. It also enhances the oxidation of C_1 sequence and disfavours the C_2 sequence. Consequently, a reduction of C_2 intermediate specie mole fraction could be observed.

13/03371 Modeling of soot formation during partial oxidation of producer gas

Svensson, H. *et al. Fuel*, 2013, 106, 271–278.

Soot formation in a reverse-flow partial-oxidation reactor for reforming of gasifier producer gas has been studied. The process was modelled using a detailed reaction mechanism to describe the kinetics of soot formation. The numerical model was validated against experimental data from the literature and showed good agreement with reported data. Nine cases with different gas compositions were simulated in order to study the effects of water, hydrogen and methane content of the gas. The CO and CO_2 contents, as well as the tar content of the gas, were also varied to study their effects on soot formation. The results showed that the steam and hydrogen content of the inlet gas had less impact on the soot formation than expected, while the methane content greatly influenced the soot formation. Increasing the CO_2 content of the gas reduced the amount of soot formed and gave a higher energy efficiency and methane conversion. In the case of no tar in the incoming gas the soot formation was significantly reduced. It can be concluded that removing the tar in an energy efficient way, prior to the partial oxidation reactor, will greatly reduce the amount of soot formed. Further investigation of tar reduction is needed and experimental research into this process is on-going.

13/03372 NO_x control in coal combustion by combining biomass co-firing, oxygen enrichment and SNCR

Daood, S. S. *et al. Fuel*, 2013, 105, 283–292.

There has been renewed interest in evaluating NO_x emission control by selective non-catalytic reduction (SNCR) combined with biomass co-firing to meet impending enforcement of NO_x emission limits for power generation plant. Oxygen enrichment for the concentration of CO_2 in the flue gas has been observed in this work to have benefits for NO_x emission control. This paper presents new information on the effect of combining biomass co-firing with SNCR under various oxygen enriched and air-staging conditions performed in the 20 kW combustion facility. Biomass has a higher tendency to generate CO and produced better reductions in NO_x emission with and without using SNCR. NO reduction of around 80% were attained using SNCR for 15% and 50% blending ratios of biomasses at 21% overall O_2 concentration for unstaged combustion. Whereas, a range of 40–80% NO reductions were attained for coal (Russian coal) and 15% co-fired biomasses with 3.1–5.5% overall O_2 concentration at 22–31% levels of flame staging. Moreover, it was found that better NO_x removal efficiency was attained for higher NO_x emission baselines under both oxygen enriched and normal firing conditions. However, SNCR NO_x control for both coal or coal-biomass blends was observed to produce higher NO_x reductions during O_2 enrichment, believed to be due to the self-sustained NO_x reduction reactions. Hence, NO_x control by SNCR, oxygen enriched co-firing in power station boilers would result in lower NO_x emissions and higher CO_2 concentration for efficient scrubbing with better carbon burnouts.

13/03373 Pyrolysis of high-ash sewage sludge in a circulating fluidized bed reactor for production of liquids rich in heterocyclic nitrogenated compounds

Zuo, W. *et al. Bioresource Technology*, 2013, 127, 44–48.

A circulating fluidized bed reactor was used for pyrolysing sewage sludge with a high ash content to produce liquids rich in heterocyclic nitrogenated compounds. GC/MS and FTIR analyses showed that heterocyclic nitrogenated compounds and hydrocarbons made up 38.5–61.21% and 2.24–17.48% of the pyrolysis liquids, respectively. A fluidized gas velocity of 1.13 m/s, a sludge feed rate of 10.78 kg/h and a particle size of 1–2 mm promoted heterocyclic nitrogenated compound production. Utilizing heterocyclic nitrogenated compounds as chemical feedstock could be a way for offsetting the cost of sewage sludge treatment.

13/03374 Satellite based analysis of fire–carbon monoxide relationships from forest and agricultural residue burning (2003–2011)

Vadrevu, K. P. *et al. Atmospheric Environment*, 2013, 64, 179–191.

Carbon monoxide (CO) is an important greenhouse gas that is emitted during the incomplete combustion of biomass burning. This study assessed the measurements of pollution in the troposphere (MOPITT) CO retrievals from two different biomass-burning regions, fires in the evergreen forests of north-east India and agriculture residue fires, Punjab, India. The authors analysed long-term trends (2003–2011) in CO retrievals and fire–CO relationships including CO profiles at nine different atmospheric levels. Over a 10-year period, the mean monthly CO for north-east India ranged from 140.86 ppmv (-1σ) to 348.85 ppbv $(+1\sigma)$ with a mean CO of 244.85 ppbv. They observed a clear increase in CO signal from February to March followed by a decrease in May coinciding with the fire signal. In Punjab, the mean monthly CO ranged from 158.21 ppbv (-1σ) to 286.40 ppbv $(+1\sigma)$ with a mean CO of 222.30 ppbv. Comparison of mean CO during the peak fire months suggested relatively higher CO (439.06 ppbv) during March (evergreen forest burning) than October (194.83 ppbv) agricultural residue burning. The authors found MODIS fire radiative power (FRP) as a stronger predictor of surface CO signal than the fire counts in the evergreen forest fires. The segmented regression model fitted using nine years of FRP–CO data was useful in finding the FRP threshold impact on CO concentrations in the evergreen forests. To explain the low correlation between fires and MOPITT CO signal from the agricultural residue fires, the authors used the CALIPSO data to infer the smoke plume heights. Results suggested an average smoke plume height of 2.2 km during the peak biomass burning month from agricultural fires, compared to 4.61 km from evergreen forest fires. Overall, the MODIS FRP and CALIPSO data were useful in understanding the MOPITT CO sensitivity to fires.

13/03375 The effect of elevated water content on swirl-stabilized ethanol/air flames

Breaux, B. B. and Acharya, S. *Fuel*, 2013, 105, 90–102.

Ethanol is currently being considered as a potential alternative to traditional fuels. This study examines the use of hydrous ethanol in lieu of fossil fuels or anhydrous ethanol in order to reduce the production cost associated with ethanol. Experiments are conducted in a swirl-stabilized combustor, representative of a gas turbine and hydrous ethanol ranging from 0% to 40% water by volume are tested. A stable flame was achieved for fuels up to 35% water and the lean blow out limit was determined for these fuels. Fuels ranging from 0% to 20% water were tested in greater detail which included thermal mapping of the flame, exhaust temperature measurements, exhaust NO_x, CO_2, and O_2 measurement, as well as CH* and OH* imaging of the flame. Equivalence ratio within the combustor was varied to include 0.6, 0.8, 1.0 and 1.1, representing extremely lean, lean, stoichiometric, and rich test conditions, respectively. Results revealed that the exhaust heat rate, combustion efficiency, and combustor thermal efficiency were not affected negatively by elevated water content up to 20%. However, the flame temperature did generally decrease as a result of water addition, particularly in the lower flame region. CH*/OH* emissions in the lower-flame region were also appreciably reduced due to the parasitic heat load of water vaporization and local quenching in the lower parts of the flame. The practical consequence of burning hydrous fuel was reduced exhaust temperature. Reduced peak temperatures lead to reductions of exhaust NO_x at all test conditions. This study indicates that hydrous ethanol with up to 20% water can potentially be used in lieu of the more expensive anhydrous ethanol for combustion applications.

Fire safety

13/03376 A new mathematical quantification of wind-blown flame tilt angle of hydrocarbon pool fires with a new global correlation model

Hu, L. *et al. Fuel*, 2013, 106, 730–736.

A new mathematical methodology is brought forward in this paper to objectively quantify the flame tilt angle based on flame appearance intermittency spatial distribution obtained from the flame images series recorded in the experiments, in counteracting the uncertainty in traditional method due to the fact of extensive vibration nature of the flame in a wind. The flame tilt angle is determined based on a proposed sum function of the product of multiplication of $p(x, y)$ as probability of flame appearance at each pixel, by $D(x, y)$ as perpendicular distance from the pixel to a threshold line originated from the flame base centre. The flame tilt angle is solved mathematically as the angle of the threshold line when the above sum function at the two sides of the threshold line in the flame intermittency distribution contour are early equal. Experiments are carried out for ethanol and heptane square pool fires with dimensions of 10, 15, 20 and 25 cm in wind speed of 0–2.5 m/s. The tilt angles of the flames in the experiments determined by above mathematical method are compared with previous models reported in the literature. A new dimensionless global parameter, equating the wind speed by a characteristic uprising velocity of the flame supported by the buoyancy strength of the pool fire, is further proposed, which is shown to better converge and correlate the flame tilt angle data than previous models.

13/03377 A review of fire processes modeling of combustible materials under external heat flux

Shi, L. and Chew, M. Y. L. *Fuel*, 2013, 106, 30–50.

One-dimensional model is fundamental to two- or three-dimensional modelling of combustible materials, which can be classified into wood, non-charring polymer, charring polymer and intumescent polymer according to their characteristics. Four fire processes are involved in fire development, such as thermal process, physical process, chemical process and failure process. Consideration of all four fire processes for these combustible materials is significant to modelling accuracy and application fields. Therefore, the state of the art of one-dimensional modelling describing all four fire processes of woods, non-charring polymers, charring polymers and intumescent polymers under external heat flux was reviewed. A summary of typical considerations in previous one-dimensional models was provided, including heat conduction, pyrolysis, production of gas volatiles, volume change, water evaporation, internal gas pressure, properties of permeability and porosity, and mechanical behaviours. Empirical models and critical data of fire processes were also collected for modelling input. This paper can provide a guide to one-dimensional modelling and build basis for two- and three-dimensional modelling.

13/03378 Combustion and flame spread on fuel-soaked porous solids

Zanganeh, J. *et al. Progress in Energy and Combustion Science*, 2013, 39, (4), 320–339.

From a fire safety perspective, flame spread and combustion caused by spillage of liquid fuel on the ground are important to be considered and treated in a proper way to minimize and possibly eliminate their risks. Although changing the contaminated porous media (e.g. soil) is the best way of reducing fire risks, it is not possible if the contaminated area is too vast. Some studies have recommended that combustion can be used as the easiest and cheapest soil decontamination method if it is done properly. However, if the fuel penetrates deeply into the ground, there could be substantial fuel residue remaining in the soil even after the combustion cleaning process. The concern here is whether or not this residual fuel can trigger another fire. Thus, in a practical situation, soil decontamination can only be achieved by combustion when the fuel soaked layer in the ground is shallow and is confirmed by a thorough sampling program to ensure the residual fire risk is negligible. In addition, presented information and relevant factors interact can assist a fire engineer to make an assessment of fire risks associated with fuel-soaked porous solids. Fire engineers can use these data to predict and estimate flame spread velocity and its behaviour for different fuels and under different conditions. The predicted data then can be taken into consideration while designing the fire safety systems to eliminate or reduce the flame spread risk from the fire zone to the nearby buildings, instruments and properties. Typically, the rate of flame spread, heat transfer, fuel burning rate, temperature distribution, boundary and initial condition under different circumstances can be used as required input values in some relevant fire and combustion modelling programs such as Fire Dynamic Simulator or Fluent. They can also be used to validate the results obtained from the modelling programs and verify the program if required. Further research and guidance material such as improving the integration of fire detectors and suppression systems response time could be undertaken on these aspects.

13/03379 Inhibitory action of flame retardant on the dynamic evolution of asphalt pyrolysis volatiles

Xu, T. *et al. Fuel*, 2013, 105, 757–763.

It is important to inhibit the pyrolysis behaviour of asphalt binder for improving its flame retardancy. The inhibitory effects of magnesium hydroxide (MH) on the asphalt pyrolysis were investigated in this study. The results indicated the thermal stability of asphalt materials was improved by MH. The starting time of asphalt pyrolysis was delayed by MH in a timely manner, and the releasing amount of gaseous products was also reduced. The qualitative composition of main volatiles evolved from asphalt/MH composite is similar to that of pure asphalt binder, including carbon dioxide, methane, water, carbon monoxide, sulfur dioxide, aromatics, hydrocarbons, etc. Each main volatile was emitted from different chemical compositions of asphalt binder at various temperature ranges. It was found that the reaction between asphalt binder and MH was only a physical blending process. The fire safety of asphalt materials was elevated by MH, but no additional secondary hazards were generated. The flame-retarding purpose of asphalt materials was achieved because of the effects of cooling, blocking and diluting in the condensed and gas phase due to MH decomposition. It is believed that MH can be utilized as a new environment-friendly flame retardant for asphalt binder at a lower loading.

13/03380 Lessons learned from recent fuel storage fires

Mishra, K. B. *et al. Fuel Processing Technology*, 2013, 107, 166–172.

Industrial fire and explosion hazards due to accidents in fuel storage units have gained a considerable attention in recent years. Both, the regulatory bodies and scientific communities are heavily concerned about the proper safety measures to avoid such calamities in the future. This paper aims to bring some essentials related to the hazards that arose from recent fuel storage fire accidents occurring in Buncefield, UK (2005), Puerto Rico, USA (2009) and Sitapura, India (2009). The potential similarities behind occurrence of these accidents are studied. The applicability of various methods (models) and also computer simulations to estimate the safety distances according to the international standards for both explosion and fire hazard are verified. The overpressures caused by the vapour cloud explosions (VCE) and radiation fluxes emitted by the fires are considered for respective explosion and fire hazard estimations. The prime focus is placed on the regulations laid down by the National Fire Protection Agency of the USA and the European norms.

13/03381 Nonflammable electrolyte for rechargeable lithium battery with sulfur based composite cathode materials

Lin, F. *et al. Journal of Power Sources*, 2013, 223, 18–22.

The concept of improving the safety of rechargeable lithium sulfur batteries by introducing flame retardant additives (FRs) to liquid electrolytes is primarily reported in this paper. Dimethyl methylphosphonate (DMMP) is used as a flame retardant additive to improve the thermal safety of rechargeable lithium batteries with sulfur based composite cathode materials. The electrochemical compatibility between DMMP and sulfur cathode is investigated. With 11 wt% DMMP addition, the electrolyte of 1 M $LiPF_6$/EC+EMC (1:1, v/v) is nearly non-flammable and its thermal stability is obviously improved. Cycle performance and electrochemical stability are little affected with an appropriate DMMP addition of 7–11 wt% by the analysis of electrochemical impedance spectra (EIS) and cycle performances. DMMP is a feasible choice as flame retardant additive in carbonate electrolyte for rechargeable lithium batteries with sulfur composite cathode materials.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

13/03382 A fault magnitude based strategy for effective fault classification

Lee, C. J. *et al. Chemical Engineering Research and Design*, 2013, 91, (3), 530–541.

A common approach in fault diagnosis is monitoring the deviations of measured variables from the values at normal operations to identify the root causes of faults. When the number of conceivable faults is larger than that of predictive variables, conventional approaches can yield ambiguous diagnosis results including multiple fault candidates. To address the issue, this work proposes a fault magnitude based strategy. Signed digraph is first used to identify qualitative relationships between process variables and faults. Empirical models for predicting process variables under assumed faults are then constructed with support vector regression (SVR). Fault magnitude data are projected onto principal components subspace, and the mapping from scores to fault magnitudes is learned via SVR. This model can estimate fault magnitudes and discriminate a true fault among multiple candidates when different fault magnitudes yield distinguishable responses in the monitored variables. The efficacy of the proposed approach is illustrated on an actuator benchmark problem.

13/03383 A flexible and efficient multi-agent gas turbine power plant energy management system with economic and environmental constraints

Roche, R. *et al. Applied Energy*, 2013, 101, 644–654.

Gas turbine power plants have characteristics that make them well-suited for applications where fast dynamics and high outputs are required, for example to accommodate variable load profiles and intermittent energy sources. However, this flexibility comes at a cost: these plants are much more expensive to operate than other types of power plants. This paper proposes a new energy management system that enables a flexible and efficient operation of gas power plants. It is based on a multi-agent system combined with an economic and environmental dispatch algorithm obtained through an optimization algorithm based on differential evolution. Simulation results for a test system based on actual data of a GE 9E turbine show that the system helps reducing operation costs by up 4.7% and NO_x emissions by up to 20.5%, and can be used with a large variety of gas power plants, as well as be adapted to evolutions in the plant structure.

13/03384 Advanced thermal treatment of auto shredder residue and refuse derived fuel

Taylor, R. *et al. Fuel*, 2013, 106, 401–409.

The disposal of end-of-life vehicles (ELVs) results in a highly heterogeneous polymeric waste stream of automobile shredder residue (ASR). Within Europe, strict legislation, such as the End-of-Life Vehicle Directive and the Landfill Directive, has imposed targets for reducing this waste stream and diverting the material away from landfill. One pathway open to recyclers is to thermally process these wastes, but the presence of chlorine and metallic species can present challenges to traditional incineration technologies. This paper discusses the use of Gasplasma®, an advanced thermal treatment technology, comprising fluidized bed oxy-steam gasification followed by plasma treatment, for ASR, refuse-derived fuel (RDF) and blends of ASR and RDF wastes. The work demonstrates the ability to process these highly heterogeneous materials achieving high energy conversion (87–94%) and virtually complete carbon conversion, producing a calorific synthetic gas (syngas) capable of being used for power generation or as a chemical feedstock. The actual conversion efficiency achieved is dependent on feed chemistry and properties. The study also shows that ash components of the feed material can be transformed into an environmentally stable vitrified product.

13/03385 Assessment of investment efficiency in a power system under performance-based regulation

Božič, D. and Pantoš, M. *Energy*, 2013, 51, 330–338.

The paper presents a new method for reliability investment decisions when a reward/penalty scheme is applied to the regulation of distribution system operators. The method was developed in order to facilitate the transition from cost-based regulation to performance-based regulation for distribution utilities. New investment planning criteria for distribution utilities subjected to the new regulatory regime are identified and mathematically formulated as a new investment efficiency index, which yields the relation between the improvement of system reliability due to the investment in the electric system and total investment costs. To determine the improvement of system reliability due to the investment in the electric network, the method uses the Monte Carlo simulation technique for the modelling of the stochastic nature of outages in electric networks, along with a linear program, which enables one to calculate load flow equations under a fault state and provides information about power deficits in the electric system. The method was tested on Slovenian distribution systems, where several investment candidates were compared in order to determine which projects need to be undertaken in order to achieve the highest possible reliability increase.

13/03386 Assessment of the consumption of water and construction materials in state-of-the-art fossil fuel power generation technologies involving CO_2 capture

Cormos, C.-C. *et al. Energy*, 2013, 51, 37–49.

This paper assesses the needs for cooling water and construction materials of pulverized coal combustion (PF), integrated gasification combined cycle (IGCC) and natural gas combined cycle (NGCC) power generation technologies with and without CCS (carbon capture and storage). Moreover, the paper evaluates how the integration of CCS technologies influences the economics and operational performance of power plants providing up-dated techno-economic indicators. The introduction of CO_2 capture results in an increase of specific water consumption compared to a conventional plant which is more significant in the cases of PF and NGCC (56–62% and 50%) than in IGCC (9–12%). Therefore, the large-scale deployment of CCS can have a significant impact on freshwater resources. The introduction of CO_2 capture also increases significantly the amount of plant construction materials. The increase is up to 100% for concrete and steel and up to 27% for copper and polyethylene. The cost of construction materials is 8–15% of total investment costs, hence any changes in their prices can have a measurable impact on the cost of a plant and hence on the competitiveness of the underlying technology.

13/03387 Combination of TOPSIS and AHP in load shedding scheme for large pulp mill electrical system

Goh, H. H. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 198–204.

The variety of powerful equipment used in the industry sector need a stable and reliable electrical supply in order for the whole system to work smoothly. This paper considers a load shedding application toward a large pulp mill electrical system using the multi-decision making methods which are the analytical hierarchy process (AHP) and the technique for order preference by similarity to ideal solution (TOPSIS) methods. Whenever there are electrical supply shortages, the load shedding method is applied to recover and stabilize the system. Load shedding is a module that sheds the higher possible load in the system to overcome the voltage shortage in the system. The objective of this paper is to extract the possible unnecessary load and determine the ranking of the load according to their importance level. The proposed methods are to test on the plant load shedding table from a paper pulp mill industry with 25 load points for practical applications.

13/03388 CO_2 capture in integrated gasification combined cycle with SEWGS – part A: thermodynamic performances

Gazzani, M. *et al. Fuel*, 2013, 105, 206–219.

This two part-paper investigates the performance of sorption enhanced water gas shift (SEWGS), an innovative system for CO_2 capture, applied to a coal fuelled integrated gasification combined cycle (IGCC). First, two reference cases based on a dry feed slagging Shell gasifier, with and without CO_2 capture, are defined. Conventional pulverized coal plant, where CO_2 capture is carried out with amine scrubbing technology, is also presented. Subsequently, SEWGS optimal integration in IGCC plant is investigated. The optimized parameters are SEWGS carbon capture ratio, CO_2 purity and number of vessels. Moreover, two different types of sorbent, 'sorbent alpha' and 'sorbent beta', are considered in order to evaluate the impact of sorbent cyclic capacity on system performances. Both sorbents capture H_2S together with CO_2 with efficiency and equipment advantages. Results show that optimal SEWGS carbon capture ratio is in the range of 95% for both sorbent alpha and sorbent beta, with the latter achieving net electric efficiency of 40%. The resulting specific energy consumption for CO_2 avoided (SPECCA) is $2.0\,MJ/kg_{CO2}$, which is 40% to 60% lower than reference IGCC and ASC reference cases respectively. Even sorbent alpha, which features a lower capacity than sorbent beta, achieves a SPECCA of about $2.5\,MJ/kg_{CO2}$ which is 30% lower than reference case, illustrating the advantages of SEWGS. Part B of this paper will discuss the economic assessment of the investigated cases in order to determine the CO_2 avoided cost.

13/03389 CO_2 capture in integrated gasification combined cycle with SEWGS – Part B: economic assessment

Manzolini, G. *et al. Fuel*, 2013, 105, 220–227.

This two-part paper investigates the performance of sorption enhanced water gas shift (SEWGS), an innovative reactor for CO_2 capture, applied to an integrated gasification combined cycle (IGCC). In part A, different SEWGS working conditions were investigated outlining several advantages and performance differences. A comparison of two sorbents is also performed. This paper presents the economic assessment of the investigated SEWGS cases together with the reference plants selected for electricity production. Both pulverized coal and integrated gasifier combined cycle were introduced as reference technologies. Results show that with the base sorbent performances the calculated cost of CO_2 avoided is about €30/t_{CO2}, which is lower than IGCC with CO_2 capture via Selexol and pulverized coal with amine scrubbing. SEWGS allows reducing investment costs, thanks to the simultaneous CO_2 and H_2S separation, and efficiency penalties compared to Selexol. The adoption of a sorbent with improved performances further reduces the cost of CO_2 avoided down to €23/t_{CO2}: advantages of new sorbent are both in terms of equipment savings and lower efficiency penalty. The optimal SEWGS carbon capture rate is between 95% and 98%. Sensitivity analysis on SEWGS equipment cost showed that increasing investment cost of 50%, the impact on cost of CO_2 avoided would be minimal, about €3/t_{CO2}.

13/03390 Efficiency of wet feed IGCC (integrated gasification combined cycle) systems with coal–water slurry preheating vaporization technology

Zhang, J. *et al. Energy*, 2013, 51, 137–145.

Coal–water slurry (CWS) preheating vaporization technology is an important new technology for the future development of integrated gasification combined cycle (IGCC) systems, providing an opportunity to improve the energy efficiency of wet-feed gasification processes. This paper systematically analysed the influence of integration of this technology on the energy efficiency performance of wet-feed IGCC systems with or without carbon capture. The authors designed, simulated and compared 10 cases of IGCC systems, including three wet-feed IGCC systems with distinct integration modes for CWS preheating technology, one traditional wet-feed IGCC and one dry-feed IGCC as reference cases, all of which have one case with carbon capture and another case without carbon capture. The results indicate that, without carbon capture, the overall energy efficiencies of wet-feed IGCC systems integrated with this technology are 1–5% higher than that of the original wet-feed IGCC system, depending on the integration mode. When carbon capture is introduced, the overall energy efficiencies of wet-feed IGCC systems integrated with this technology are close to or even higher than that of the dry-feed IGCC system.

13/03391 Electrochemical performance and thermal cyclicability of industrial-sized anode supported planar solid oxide fuel cells

Luo, J. *et al. Journal of Power Sources*, 2013, 224, 37–41.

Industrial-sized planar anode-supported SOFC cells with a cell dimension of $15 \times 15 \times 0.1$ cm and an active area of $13 \times 13\,\mathrm{cm}^2$ are fabricated through a processing route of tape casting-screen printing-cofiring. Electrochemical performance and thermal cyclicability of the cell are evaluated in a single cell stack at 750 °C with H_2 as the fuel and air as the oxidant. With a gas flow rate of $3\,\mathrm{L\,min}^{-1}$, the initial open circuit voltage (OCV) is 1164 mV, and the stack demonstrates a power density of $380\,\mathrm{mW\,cm}^{-2}$ at $473\,\mathrm{mA\,cm}^{-2}$ with an extrapolated maximum power output of 100 W. After three thermal cycles, the reduction of the stack output voltage is around 5%, and the OCV is maintained at a level above 1145 mV. Based on the obtained results, issues related to stack performance, such as cell quality, contact resistance and sealing, are discussed.

13/03392 Energy consumption optimization of a continuous ice cream process

González-Ramírez, J. E. *et al. Energy Conversion and Management*, 2013, 70, 230–238.

This work investigates potential energy saves in an ice cream freezer by using a variable speed compressor and optimization's methodology for operating conditions during the process. Two configurations to control the refrigeration capacity were analysed, the first one, modifies the pressure through the pilot control valve (conventional refrigeration system) and the second one with a variable speed compressor, both with a float expansion valve. Variable speed compressor configuration has showed the highest coefficient of performance and around of 30% less of energy consumption than the conventional one. The optimization of operating conditions in order to minimize the energy consumption is also presented. It was calculated only in France, for all ice cream and sorbet production, it is possible to save energy between 11 and 14 MWh per year by optimizing the operation of the refrigeration system through a variable speed compressor configuration.

13/03393 Fixed bed downdraft gasification of paper industry wastes

Ouadi, M. *et al. Applied Energy*, 2013, 103, 692–699.

The two main wastes generated from secondary fibre paper mills are rejects (composed mainly of plastics and fibres) and de-inking sludge, both of which are evolved from the pulping process during paper manufacture. The current practice for the disposal of these wastes is either by land-spreading or land-filling. This work explores the gasification of blends of pre-conditioned rejects and de-inking sludge pellets with mixed wood chips in an Imbert type fixed bed downdraft gasifier with a maximum feeding capacity of 10 kg/h. The producer gases evolved would generate combined heat and power (CHP) in an internal combustion engine. The results show that as much as 80 wt% of a brown paper mill's rejects (consisting of 20 wt% mixed plastics and 80 wt% paper fibres) could be successfully gasified in a blend with 20 wt% mixed wood chips. The producer gas composition was 16.24% H_2, 23.34% CO, 12.71% CO_2 5.21% CH_4 and 42.49% N_2 (v/v%) with a higher heating value of $7.3\,\mathrm{MJ/N\,m}^3$. After the removal of tar and water condensate the producer gas was of sufficient calorific value and flow rate to power a 10 kWe gas engine. Some blends using rejects from other mill types were not successful, and the limiting factor was usually the agglomeration of plastics present within the fuel.

13/03394 Grindability determination of torrefied biomass materials using the hybrid work index

Van Essendelft, D. T. *et al. Fuel*, 2013, 105, 103–111.

The grindability of torrefied biomass materials is a difficult parameter to evaluate due to its inhomogeneous character and non-uniform morphology. However, it is necessary to develop a grinding test that is representative of the wide-ranging character of biomass and torrefied biomass materials. Previous research has shown that resistance to impact milling (RIM) can be linearly correlated to thermally driven weight loss in biomass. In particular, the RIM equipment was found to supply the right energy level to physically break down structurally deficient biomass materials while leaving the untouched material relatively intact. However, the RIM procedure was not designed to extract the comminution energy. Alternatively, the bond work index (BWI) procedure was developed to accurately assess the grinding energy of brittle materials. However, the milling energy is too low to be effective for biomass comminution. In this research, the BWI procedure was utilized with the ball–mill approach in the RIM test to evaluate torrefied biomass materials. The hybridized procedure has been shown to be both correlated to energy consumption and sensitive to degree of torrefaction. The proposed hybrid work index is certainly useful for assessing torrefaction in a laboratory environment, but it may also be correlated to grinding energy at industrial scales.

13/03395 High pressure plant for heterogeneous catalytic CO_2 hydrogenation reactions in a continuous flow microreactor

Tidona, B. *et al. Chemical Engineering and Processing: Process Intensification*, 2013, 65, 53–57.

The CO_2 hydrogenation to methanol is favoured by high pressure from the thermodynamic point of view. Mostly experimental work on this reaction is limited at 400 bar due to technical and safety reasons. This study presents a high pressure plant able to conduct CO_2 hydrogenation reactions at pressures up to 950 bar in a capillary microreactor; it focuses on the influence of pressure concerning process intensification. To validate the plant functionality the reverse water–gas shift (RWGS) reaction was conducted over a 1 wt% Pt/CeO_2 catalyst at 450 °C and between 200 and 950 bar. A mass flow controller for hydrogen was developed due to lack of commercial available hydrogen mass flow controller able to work in the micro liter per minute range and up to 1000 bar. Additional to the RWGS reaction two more reactions take place. The first is the CO disproportionation reaction which results in deposited carbon on the catalyst. The second is the subsequent hydrogenation of carbon to methane. The experimentally determined CO_2 conversion is clearly below the equilibrium of the entire reaction network, hence the reaction is kinetically limited. The reaction performance increases with pressure showing process intensification.

13/03396 Industrial excess heat deliveries to Swedish district heating networks: drop it like it's hot

Broberg, S. *et al. Energy Policy*, 2012, 51, 332–339.

Using industrial excess heat in district heating (DH) networks reduces the need for primary energy and is considered efficient resource use. The conditions of Swedish DH markets are under political discussion in the third party access (TPA) proposal, which would facilitate the delivery of firms' industrial excess heat to DH networks. This paper estimates and discusses the untapped potential for excess heat deliveries to DH networks and considers whether the realization of this potential would be affected by altered DH market conditions. The results identify untapped potential for industrial excess heat deliveries, and calculations based on estimated investment costs and revenues indicate that realizing the TPA proposal could enable profitable excess heat investments.

13/03397 Optimal operational adjustment in multi-functional energy systems in response to process inoperability

Kasivisvanathan, H. *et al. Applied Energy*, 2013, 102, 492–500.

Multi-functional energy systems such as biorefineries and polygeneration plants are able to efficiently produce product portfolios by taking advantage of inherent opportunities for optimal integration among process units. Thus, such systems provide valuable solutions towards efficient, sustainable and economically viable production of energy, fuels, utilities and commodity chemicals. On the other hand, the high level of interdependency among process units within such industrial plants is also a potential disadvantage, since the inoperability of one process unit propagates upstream and downstream through the process network to affect other operations. This paper presents a simple mixed-integer linear programming (MILP) model for determining optimal process adjustments in multi-functional energy systems as a result of partial inoperability. The methodology assumes that partial or complete inoperability of some of the process units within the plant forces it to operate away from the baseline state that it was originally designed for. For example, such emergency conditions may result from damaged process equipment. The MILP model determines the optimal reallocation of process streams and operating levels of the process units in order to maximize operating profits from the product portfolio.

13/03398 Performance of entrained flow and fluidised bed biomass gasifiers on different scales

Tremel, A. *et al. Energy Conversion and Management*, 2013, 69, 95–106.
This biomass gasification process study compares the energetic and economic efficiencies of a dual fluidized bed and an oxygen-blown entrained flow gasifier from 10 $\mathrm{MW_{th}}$ to 500 $\mathrm{MW_{th}}$. While fluidized bed gasification became the most applied technology for biomass in small and medium scale facilities, entrained flow gasification technology is still used exclusively for industrial scale coal gasification. Therefore, it is analysed whether and for which capacity the entrained flow technology is an energetically and economically efficient option for the thermochemical conversion of biomass. Special attention is given to the pre-conditioning methods for biomass to enable the application in an entrained flow gasifier. Process chains are selected for the two gasifier types and subsequently transformed to simulation models. The simulation results show that the performance of both gasifier types is similar for the production of a pressurized product gas (2.5 MPa). The cold gas efficiency of the fluidized bed is 76–79% and about 0.5–2 percentage points higher than for the entrained flow reactor. The net efficiencies of both technologies are similar and between 64% and 71% depending on scale. The auxiliary power consumption of the entrained flow reactor is caused mainly by the air separation unit, the oxygen compression, and the fuel pulverization, whereas the fluidized bed requires additional power mainly for gas compression. The costs for the product gas are determined as between €4.2 cent/kWh (500 $\mathrm{MW_{th}}$) and €7.4 cent/kWh (10 $\mathrm{MW_{th}}$) in the economic analysis of both technologies. The study indicates that the entrained flow reactor is competitive technology for biomass gasification also on a smaller scale.

13/03399 Thermoeconomic evaluation and optimization of a Brayton–Rankine–Kalina combined triple power cycle

Singh, O. K. and Kaushik, S. C. *Energy Conversion and Management*, 2013, 71, 32–42.
This paper presents thermoeconomic analysis and optimization of a Brayton–Rankine–Kalina combined triple power cycle using specific exergy costing (SPECO) methodology. Cost-balance and auxiliary equations are formulated for each component and for each node and solved through a MATLAB program to get the average cost per unit exergy at different state points. To evaluate the cost effectiveness of the system, the values of thermoeconomic variables for each component are calculated. Large relative cost difference is observed in the steam turbine, heat recovery steam generators, combustion chambers, compressors, recuperators and ammonia–water evaporator. Therefore, these components require greater attention. The performance of steam turbine, combustion chambers, recuperators and ammonia–water evaporator can be appreciably improved by capital investment into more efficient design due to their low values of exergoeconomic factor. The performance of HRSG's can be improved only marginally due to slightly higher value of exergoeconomic factor but no such recommendation can be made for the compressors which have a quite high value of exergoeconomic factor. The objective function of the thermoeconomic optimization is the minimization of the total cost rate for the whole plant. Its minimum value is found to occur at a gas cycle pressure ratio of around 14. Decreasing inlet air temperature decreases this objective function parameter significantly while increasing relative humidity causes a small decrease in it.

13/03400 Vermistabilization of paper mill wastewater sludge using *Eisenia fetida*

Negi, R. and Suthar, S. *Bioresource Technology*, 2013, 128, 193–198.
Vermistabilization of paper mill wastewater sludge (PMS) spiked with cow dung (CD) at ratios of 0%, 25%, 50%, 75%, and 100% was carried out employing the earthworm, *Eisenia fetida*. A total of five treatments were established and changes in chemical and microbial properties of mixtures were observed. Vermistabilization caused decreases in total organic carbon, C:N ratio and cellulose by 1.2–1.5, 4.6–14.6, and 2.3–9.7-fold, respectively, but increases in pH, electrical conductivity, ash content, $_{\mathrm{tot}}\mathrm{N}$, $_{\mathrm{avail}}\mathrm{P}$, $_{\mathrm{tot}}\mathrm{P}$, $_{\mathrm{exch}}\mathrm{K}$, Ca, Na, and $\mathrm{N{-}NO_3^-}$ of 1.06–1.11, 1.2–1.6, 1.3–1.6, 3.8–11.5, 4.1–6.5, 5.7–10.3, 1.7–2.0, 1.16–1.24, 1.23–1.45, 4.2–13.4-folds, respectively. PMS with 25–50% of CD showed the maximum mineralization rate. The fungal, bacterial and actinomycetes population increased 2.5–3.71, 3.13–8.96, and 5.71–9.48-fold, respectively after vermistabilization. The high level of plant-available nutrients indicates the suitability of vermistabilized material for agronomic uses.

13/03401 Volumetric mass transfer coefficient and hydrodynamic study of a new self-inducing turbine

Achouri, R. *et al. Energy Conversion and Management*, 2013, 71, 69–75.
Self-inducing turbines are among mobile agitations which present a very interesting potential in terms of energy in the field of wastewater treatment by activated sludge. Often, the reactions involved in this type of contactors are limited by the gas–liquid mass transfer. The objective of this experimental work is the determination of the oxygenation capacity of a new self-inducing turbine, a holed hollow cylinder, having a thickness of $W = 1.5$ cm and a diameter $D = 9$ cm, with six holes having a diameter of 0.5 cm each. During this experimental work, the authors evaluated the volumetric mass transfer coefficient k_La, which is directly related to the oxygenation capacity (OC) and this for various rotational speeds of the turbine as well as for various submergences. The authors finally succeeded in finding an empirical correlation for this new self-inducing turbine. The most common method used to estimate experimentally the coefficient k_La is the technique of dynamic oxygenation and deoxygenation. The paper concludes that this new turbine has a satisfying aeration capacity, which increases with the increase of the rotational speed, and decreases when increasing the submergence of the impeller.

10 SPACE HEATING AND COOLING/HEAT PUMPS

13/03402 A comparative study of longitudinal fins of rectangular, trapezoidal and concave parabolic profiles with multiple nonlinearities

Torabi, M. *et al. Energy*, 2013, 51, 243–256.
This paper establishes the performance characteristics of convective–radiative longitudinal fins of rectangular, trapezoidal and concave parabolic profiles with simultaneous variation of thermal conductivity, heat transfer coefficient and surface emissivity with temperature. The convection and radiation sink temperatures were assumed to be non-zero. The calculations are carried out using the differential transformation method (DTM). The accuracy of the DTM is confirmed by comparing its predictions with the results from an analytical solution and a well-tested numerical procedure. A new idea of volume adjusted fin heat transfer rate, fin effectiveness, and fin efficiency is introduced to compare the performances of trapezoidal and concave parabolic fins with the rectangular fin. Results presented illustrate the effects of thermal conductivity parameter, emissivity parameter, convection–conduction parameter, radiation–conduction parameter, and dimensionless convection and radiation sink temperatures on the performance of fins.

13/03403 A coupled numerical approach on museum air conditioning: energy and fluid-dynamic analysis

Ascione, F. *et al. Applied Energy*, 2013, 103, 416–427.
In the museum environment, the temporal stability and the spatial uniformity of the indoor microclimatic parameters are necessary primarily for the correct artwork conservation and then for the occupant thermal comfort. Therefore, a HVAC system is usually necessary. This paper above all emphasizes the integration of building energy performance simulation (BEPS) and computational fluid dynamics (CFD) codes. This coupled numerical approach can provide accurate information about both the HVAC system energy request and the indoor microclimatic control (temporal and spatial distribution of the parameters). Then, a case study concerning a typical museum exhibition room is examined. The annual energy request for three types of all-air system, as well as the temporal variation of indoor temperature and relative humidity, is evaluated by means of a BEPS code. Energy savings can be obtained using a system with desiccant wheel (11%) or enthalpy wheel (9%), compared to the base system. As regards indoor relative humidity control, this is more critical for summer conditions, and the best performance is obtained by the system with desiccant wheel. Then, the spatial microclimatic control is analysed by means of a CFD analysis, for various thermal load conditions and different air diffusion equipment. The best performances are obtained by using the swirling (vortex) diffusers; also the perimetrical stripes of slot diffusers show satisfactory performances. Finally, in order to evaluate the ability of air diffusion equipment to assure good ventilation effectiveness, an analysis of the mean age of air is carried out too.

13/03404 A measuring campaign of thermal conductance in situ and possible impacts on net energy demand in buildings

Cesaratto, P. G. and De Carli, M. *Energy and Buildings*, 2013, 59, 29–36.
In recent many studies concerning the evaluation of the thermal conductance of building elements via measurements have been carried out. Thermal conductance value has to be found from the analysis of recorded temperature and heat flux profiles. The determination of this property *in situ* would allow a more accurate evaluation of the real heating energy demand of a building. Papers discussing different data analysis methods are present in the literature and measurements on test components under real conditions and evaluations on different theoretical aspects by means of numerical simulations have already been developed. This paper aims to widen the existent literature of the

in situ evaluation of the thermal conductance, through the discussion of the results of a measuring campaign which lasted 4 years on real buildings, and by comparing the reference specific thermal conductance (C) values with those computed on the basis of the measurements. Various tests on the same elements are discussed. Finally, an analysis on the influence of the C value on the evaluation of the net heating energy demand of a building in different climates is presented.

13/03405 A new design of metal-sheet cool roof using PCM

Chou, H.-M. *et al. Energy and Buildings*, 2013, 57, 42–50.

Heat flow through the roof contributes in the total heat gain of a building. The contribution becomes more severe for single story houses covered by metal sheet roofing. This paper presents a new design for metal sheet roofing structure in order to improve its total thermal resistance. Its main concept is to utilize phase change material properties to first absorb the downward heat flow made by incident solar radiation to the room and then release it back to the environment by means of the naturally favoured external convection especially during the nocturnal cycle. Experimental and numerical analyses have been conducted to compare thermal performance of the new design and the available normal roofing with the same materials and colour. A general mathematic equation system, which can be used for further evaluation and prediction of the new design with varied parameters, has been derived for the thermal process through the roof. The results show that the new design can effectively reduce the downward thermal flow through the roof into the house. As a consequence, the cooling load of the house can be lower and more electricity for cooling attempt can be saved.

13/03406 A three-dimensional numerical model of borehole heat exchanger heat transfer and fluid flow

Rees, S. J. and He, M. *Geothermics*, 2013, 46, 1–13.

Common approaches to the simulation of borehole heat exchangers assume heat transfer within the circulating fluid and grout to be in a quasi-steady state and ignore axial conduction heat transfer. This paper presents a numerical model that is three-dimensional, includes explicit representations of the circulating fluid and other borehole components, and so allows calculation of dynamic behaviours over short and long timescales. The model is formulated using a finite volume approach using multi-block meshes to represent the ground, pipes, fluid and grout in a geometrically correct manner. Validation and verification exercises are presented that use both short timescale data to identify transport delay effects, and long timescale data to examine the modelling of seasonal heat transfer and show the model is capable of predicting outlet temperatures and heat transfer rates accurately. At long timescales borehole heat transfer seems well characterized by the mean fluid and borehole wall temperature if the fluid circulating velocity is reasonably high but at lower flow rates this is not the case. Study of the short timescale dynamics has shown that non-linearities in the temperature and heat flux profiles are noticeable over the whole velocity range of practical interest. The importance of representing the thermal mass of the grout and the dynamic variations in temperature gradient as well as the fluid transport within the borehole has been highlighted. Implications for simplified modelling approaches are also discussed.

13/03407 Analysis of temperature and stress distribution of superheater tubes after attemperation or sootblower activation

Madejski, P. and Taler, D. *Energy Conversion and Management*, 2013, 71, 131–137.

Superheaters are characterized by high metal temperatures due to higher steam temperature and low heat transfer coefficients on the tube inner surfaces. Superheaters have especially difficult operating conditions, particularly during attemperator and sootblower activations, when temperature and steam flow rate as well as tube wall temperature change with time. The results obtained from the temperature and stress analysis based on the finite volume method demonstrate that double omega superheater tubes work in adverse conditions. High gas corrosion failures may occur at the tube corners because of high metal temperatures. Also the stresses at the corners are high.

13/03408 Bi-layered and inclined porous collector: optimum heat and mass transfer

Hadidi, N. *et al. Energy*, 2013, 51, 422–430.

This paper presents the results of a numerical study of double-diffusive convection in an inclined rectangular collector filled with two parallel porous layers. Each porous layer is considered homogeneous, isotropic and saturated with the same fluid. The vertical walls of porous cavity are subjected to uniform temperature and concentration whereas the other surfaces are assumed to be adiabatic and impermeable. The set of equations governing the heat and mass coupled problem within the enclosure are solved numerically. The numerical results are presented and analysed in terms of streamlines, isotherms, isoconcentrations lines and average Nusselt and Sherwood numbers. A scale analysis is used to characterize the effect of the permeability ratio on the heat and mass transfer. It is found that the numerical solutions of the full governing equations are in good agreement with the scaling results for some specific conditions. Optimum operating tilted angle are deduced.

13/03409 Combined constructal and exergy optimization of thermochemical reactors for high temperature heat storage

Neveu, P. *et al. Energy Conversion and Management*, 2013, 71, 186–198.

High temperature heat storage is one of the key points for the development of solar power plants. Using reversible solid–gas chemical reactions is a promising solution to achieve high energy density and to reduce the storage volume. In order to achieve the high energy density, heat and mass transfer networks have to be optimized. In fact, such a reactive material presents antagonist behaviours for heat conductivity and gas permeability: increasing the reactive material density (i.e. the energy density) increases heat conductivity, but dramatically decreases permeability. An optimum has to be found. A method, combining constructal approach and exergy analysis is presented in this paper and applied to a solid/gas reactor, exchanging heat and matter (gas) with its surrounding. The gas is produced by the conversion of a solid S1 in a solid S2, implying a reaction heat. The method consists in evaluating the global entropy production of an elemental volume and minimizing it under two constraints: a given power density (kW/m^3) and a given volume (i.e. given storage capacity), using Lagrange multipliers method. Then, a construction is done. The optimal shape and the number of elemental volumes constituting the reactor are searched. Taking into account heat and mass transfers, two networks emerge from the optimal construction: a heat conductive material network and a gas diffusers networks. The size of the conductive ‘fins’ and gas diffusers only depends on the properties of the reactive material (heat conductivity, permeability), the reactive gas (viscosity, pressure) and the heat of reaction. One important result is that global exergy destruction ex_d could be put in a very attractive form: $\dot{ex}_d = Z\dot{q}^2$ where $\dot{q}$ is the thermal power consumed by the reaction (W) and Z is named exergy impedance, regarding analogy with electric Joule effect ($\dot{ex}_d = Zi^2$).

13/03410 Design, fabrication and performance tests for a polymer-based flexible flat heat pipe

Hsieh, S.-S. and Yang, Y.-R. *Energy Conversion and Management*, 2013, 70, 10–19.

This study reports on the novel design, fabrication and performance tests for a polymer-based flexible flat heat pipe (FHP) with a bending angle in the range of 15–90°. Each heat pipe is 4 mm thick, 20 mm wide and 80 mm long, with two layers of No. 250 copper mesh as the wicking material. A copper/silicone rubber hybrid structure is designed and fabricated to achieve the flexibility of the heat pipe. Thermal characteristics are measured and studied for de-ionized water under different working conditions. Experimental results reveal that a bending angle of 15° on the vertical plane has a better thermal performance than those of heat pipes with/without bending. In addition, a higher power of 12.67 W can be transferred/delivered.

13/03411 Enthalpy and temperature of the phase change solid–liquid – an analysis of data of the elements using information on their structure

Mehling, H. *Solar Energy*, 2013, 88, 71–79.

Latent heat storage with materials undergoing a phase change solid–liquid is gaining increasing interest due to its potential for applications in energy systems. The demand for optimized storage materials has led to an intensification of materials research in recent years. The research focuses mainly on developing materials with high storage density, and related to this the question what the theoretical limit is. For both it is necessary to understand what affects the melting enthalpy and melting temperature on the atomic and molecular level. For some material classes, especially metals, empiric rules or microscopic models have been developed that allow a qualitative and sometimes a rough quantitative prediction of the melting enthalpy and melting temperature. However, none of them is applicable to a wide variety of material classes or gives a general insight in the parameters affecting the melting enthalpy and melting temperature. In this paper, data of the elements with atomic number 1–95, and therefore very different material classes, are analysed. In contrast to previous investigations, the focus is on relations between melting enthalpy and melting entropy, because these values relate to the microscopic structure. The results of the analysis show that several clusters exist among the elements. The differences between these clusters in the melting enthalpy as well as in the melting entropy can largely be explained by the microscopic structure of their member elements.

13/03412 Evaluation of thermal response and performance of PHC energy pile: field experiments and numerical simulation

Park, H. *et al. Applied Energy*, 2013, 103, 12–24.

This paper presents an experimental and numerical study on evaluation of thermal response and performance of prototype precast-high strength concrete (PHC) energy pile. Short-term field thermal response tests (TRTs) were conducted for the PHC energy piles installed in partially saturated weathered granite soil deposit, in which two types of heat exchangers were considered: W and 3U-shaped heat exchangers. The TRTs were successfully simulated by three-dimensional finite element analyses employing quasi-steady-state convective heat transfer boundary condition. The numerical model was applied to simulate 3-day TRTs and the effective thermal conductivities were analogous to lab-measurement. However, the thermal resistances were close to half of those estimated by conventional one-dimensional series model, which may be caused by small equivalent diameter considered in the series model and consequent overestimation of grout thermal resistance. The 3-h heat resistance of the energy pile with W heat exchanger predicted from thermal performance simulation was predicted to be almost half of a finding in an earlier study. It may imply that the thermal conductivity of PHC energy pile and weathered granite soil ground not only considered in this study but also common in Korean practice can provide relatively favourable thermal efficiency in geothermal energy extraction. Based on the finite element analyses results, the 3-month performance of energy pile was investigated with varying operation mode as 8-h intermittent and continuous operations. Only for intermediate operation, the energy pile with 3U heat exchanger was expected to provide superior performance (about 15% larger heat exchange rate) than the energy pile with W heat exchanger, while there was negligible difference for continuous operation. The results may indicate that a longer heat-exchanging pipe affects the performance of energy piles under peak load condition positively. Hence further integrated mock-up tests to examine the effects of heat exchange volume, as well as grout thermal properties and operation mode, may give better understanding of the thermal behaviour of energy PHC piles.

13/03413 Exergoeconomic comparison of double effect and combined ejector-double effect absorption refrigeration systems

Farshi, L. G. *et al. Applied Energy*, 2013, 103, 700–711.

At a particular temperature range, heat sources are not hot enough to drive lithium bromide double effect absorption refrigeration systems efficiently and are too hot to be used for the single effect systems because of the risk of crystallization. A combined ejector-double effect absorption cycle is a good choice to make effective use of heat sources at this temperature range for refrigeration purposes. In this study, detailed exergoeconomic analyses are performed for series flow double effect and combined ejector double effect systems in order to investigate and compare the influence of various operating parameters on investment costs of the overall systems and product cost flow rates. In addition, the proportion of component costs in the overall systems costs and exergoeconomic results are obtained. The results show that the combined cycle operates more economically compared to the double effect system.

13/03414 Exergy and energy analyses of two different types of PCM based thermal management systems for space air conditioning applications

Tyagi, V. V. *et al. Energy Conversion and Management*, 2013, 69, 1–8.

This communication presents the experimental study of phase change material (PCM)-based thermal management systems for space heating and cooling applications using energy and exergy analysis. Two different types of based thermal management system (TMS-I and TMS-II) using calcium chloride hexahydrate as the heat carrier has been designed, fabricated and studied for space heating and cooling applications at a typical climatic zone in India. In the first experimental arrangement the charging of PCM has been carried out with air conditioning system while discharging has been carried out using electric heater for both the thermal management systems. While in the second arrangement the charging of PCM has been carried out by solar energy and the discharging has been carried out by circulating the cooler ambient air during the night time. In the first experiment, TMS-I is found to be more effective than that of TMS-II while it was found to be reverse in the case of second experiment for both the charging and discharging processes not only for energetic but also for the exergetic performances.

13/03415 Experimental and numerical investigations for comparing the thermal performance of infrared reflecting insulation and of mineral wool

Hauser, G. *et al. Energy and Buildings*, 2013, 58, 131–140.

Some manufacturers of infrared reflective insulation products claim that their relatively thin products feature the same high thermal performance as 20 cm mineral wool. They maintain that their products cannot be described through conventional methods of building physics, their thermal efficiency can only be determined by *in situ* tests. Two identical buildings, which allow comparative measurements of different roof systems under identical boundary conditions, are located at an outdoor testing facility in southern Germany. In one of the attics a conventional roof system using mineral wool has been installed. Infrared reflective insulation has been applied to the other roof system. The products have been chosen to have the same thermal efficiency as specified by their manufacturers. Extensive comparative measurements have been carried out. Conventional laboratory measurements of the insulation products have been done and compared to the results of the *in situ* measurements. Furthermore, the examinations have been completed with dynamic calculations. The result is that the examined roof system with infrared reflective insulation shows typical insulation characteristics yet with lower thermal resistance. The values of the common laboratory measurements have been confirmed through the results of the *in situ* measurements. Thus, the infrared reflective products) can be described using traditional building physics.

13/03416 Experimental investigation of novel heat exchanger for low temperature lift heat pump

Lee, H. *et al. Energy*, 2013, 51, 468–474.

In this paper, the thermal and hydraulic performance of a novel low temperature lift heat exchanger (LTLHX) was experimentally investigated. The novel LTLHX was developed to improve the performance of the conventional plate type heat exchanger (PHX) under low temperature lift operating conditions. The optimized novel LTLHX was fabricated and investigated experimentally with various operating conditions. The heat transfer coefficient correlation and friction factor correlation of the water-side in the novel LTLHX were formulated from the experimental data. The overall heat transfer coefficient of the novel LTLHX with ammonia ranged from 1300 to 2000 $\mathrm{W\,K^{-1}\,m^{-2}}$, and the pressure drop per length of the water-side ranged from 4 to 10 $\mathrm{kPa\,m^{-1}}$. The refrigerant-side heat transfer coefficient ranged from 2900 to 5000 $\mathrm{W\,K^{-1}\,m^{-2}}$, and water-side heat transfer coefficient ranged from 3900 to 5100 $\mathrm{W\,K^{-1}\,m^{-2}}$. The overall heat transfer performance of the novel LTLHX was more than double that of the PHX at the same operating conditions. Moreover, the water-side pressure drop of the novel heat exchanger was drastically lower than that of the PHX. It was due to the balanced thermal and hydraulic performance of the novel heat exchanger.

13/03417 Experimental investigation on phase change material based thermal storage system for solar air heating applications

Esakkimuthu, S. *et al. Solar Energy*, 2013, 88, 144–153.

Many types of solar air heaters have been developed in India and their performance has been studied in detail. In solar dryers the drying process largely depends on the varying local weather conditions, resulting in a poor quality of the dried product. To eliminate the fluctuations in the temperature of the hot air, solar collectors are integrated with the phase change material (PCM) based thermal storage unit. The present study is aimed at investigating the feasibility of using a latent heat storage unit with HS 58, an inorganic salt based phase change material, to store the excess solar energy, and release it when the energy availability is inadequate during poor weather conditions, and to extend the period of utilization beyond the sunshine hours. Experiments were conducted to evaluate the charging and discharging characteristics of the storage unit. The effects of inlet flow rate during the charging and discharging processes were measured and reported. For the storage tank configuration and PCM ball size considered in the present investigation, the mass flow rate of 200 kg/h is able to provide a near uniform rate of heat transfer during charging and discharging processes. Further, low mass flow rate is able to utilize the maximum capacity of the storage system and to supply heat for a longer duration.

13/03418 Experimental thermal characterization of a Mediterranean residential building with PCM gypsum board walls

Mandilaras, I. *et al. Building and Environment*, 2013, 61, 93–103.

A two-storey typical family house was built in the mid-western part of Greece, comprising a load bearing steel skeleton and dry wall systems. Its walls consist of multiple layers of insulation materials and gypsum plasterboard panels containing phase change materials (PCMs) for thermal energy storage purposes. A detailed matrix of sensors was installed in different locations of all external walls of the house, as well as indoors, in order to provide detailed temperature measurements and thus lead to a thorough depiction of the house's thermal behaviour. In this work, experimental data obtained during the first year of monitoring (2011) are presented. Throughout this particular monitoring period the house purposely remained closed, unoccupied and no energy systems were installed. Hence the presented analysis focuses on the thermal characterization of the house's walling system. Average monthly temperature, decrement factor and time lag values are presented for each room–wall and are discussed with respect to their orientation and exposure to the external weather conditions. Furthermore, measurements conducted on different layers of the living room's east wall aim to examine the influence of PCMs in the wall's thermal response. It is shown that within the adopted conditions (unoccupied house/no energy systems), the thermal mass of the walling system is enhanced during late spring, early summer and autumn, due to the PCM implementation, resulting also in a decrease of the decrement factor by a further 30–40% and an increase on the time lag of approximately 100 min.

13/03419 Experimental thermal characterization of radiant barriers for building insulation

Escudero, C. *et al. Energy and Buildings*, 2013, 59, 62–72.

To obtain traceable thermal resistance of radiant barriers for building insulation laboratory tests have been carried out. Heat flow meter apparatus and guarded hot box methods have been used. The heat flow meter method has been evaluated as a method to characterize the insulating layer itself, while the guarded hot box method has been used as a tool to determine the total thermal resistance of a building component including a radiant barrier. A material with both surfaces of reflective material has been used in the study. The measurements have been carried out using two configurations in the heat flow meter apparatus: simple air chamber and double air chamber. The results have been compared with a simple analytical model of heat transfer according to ISO 6946 standard and with a computational fluid dynamic (CFD) model. The CFD model enables to assess the relationship between experimental and analytically estimated results. The main conclusion is that the laboratory tests are valid for the thermal characterization of radiant barriers. It also follows that thermal resistance of radiant barriers can be estimated with precision using the simplified ISO 6946 methodology, as long as values of the thermal properties of the reflective material such as emissivity and conductivity are reliable.

13/03420 Full-scale investigation of the dynamic heat storage of concrete decks with PCM and enhanced heat transfer surface area

Pomianowski, M. *et al. Energy and Buildings*, 2013, 59, 287–300.

The paper presents the full-scale experimental investigation of the dynamic heat storage potential of the prefabricated hollow core deck elements with and without phase change material (PCM) and with and without increased bottom surface area of the decks. In the presented investigation five types of hollow core decks with different surfaces on the bottom are investigated: reference deck made of standard concrete and flat surface, deck with special mortar grooved tiles, deck with flat mortar tiles, deck with grooved mortar and phase change material tiles, deck with flat mortar and phase change material tiles. The experimental investigation presented in the paper is performed in the specially designed modified hot box apparatus that allows maintaining periodic steady-state tests with the full-scale concrete deck elements. The presented research investigates if the extended surface area and PCM can result in the increased heat amount that can be transferred and stored in the heavy construction element during the diurnal indoor temperature fluctuations.

13/03421 Gypsum based composite materials with micro-encapsulated PCM: experimental correlations for thermal properties estimation on the basis of the composition

Toppi, T. and Mazzarella, L. *Energy and Buildings*, 2013, 57, 227–236.

Composite materials containing phase change materials (PCMs) are obtained by mixing PCM microcapsules with traditional construction materials. The composite materials thermal properties, which depend on the composition, are required when dynamic simulations of building structures containing composite material with PCM are performed. In order to avoid the need of measuring density, thermal conductivity and specific heat capacity for each possible composition, in this work correlations for the estimation of these thermal properties for gypsum based composite materials with micro-encapsulated PCM are derived. The correlations, obtained on the basis of experimental measures, give the composite material thermal properties as function of gypsum, water and PCM mass and volume fractions; it is verified that the correlations for density and thermal conductivity can be applied in the whole temperature range, including both the PCM liquid and solid phases, while a correction based on the temperature is applied for the correlation for specific heat capacity to extend its validity to the phase change temperature range. The correlations fit the experimental data with an error comparable with the measurement uncertainty and, when tested on a commercial product, they are able to predict its thermal properties with good accuracy.

13/03422 Heat storage properties of the cement mortar incorporated with composite phase change material

Li, M. *et al. Applied Energy*, 2013, 103, 393–399.

An experimental study is presented on the cement mortar incorporated with expanded graphite (EG)/paraffin composite phase change material (PCM). The composite PCM was prepared by absorbing paraffin into EG with vacuum absorption method. The heat storage cement mortar (HSCM) with proper mass fraction of the composite PCM was prepared. A testing device was designed for evaluating the heat storage effect of HSCM. Temperature variation and heat storage coefficient of HSCM were compared to those of the ordinary cement mortar (OCM). For a cubic with one HSCM board and a cubic with one OCM board, the maximum indoor centre temperature difference is 2.2 K during the heat storage and 1.5 K during the heat release process. The heat storage coefficient of HSCM board is 1.74 times of that of OCM board. The results indicate that the HSCM board has good heat storage property.

13/03423 Heat transfer enhancement through control of added perturbation velocity in flow field

Wang, J. *et al. Energy Conversion and Management*, 2013, 70, 194–201.

The characteristics of heat transfer and flow, through an added perturbation velocity, in a rectangle channel, are investigated by large eddy simulation (LES). The downstream, vertical, and upstream control strategy, which can suppress the lift of low speed streaks in the process of improving the performance of heat transfer, are adopted in numerical investigation. Taking both heat transfer and flow properties into consideration, the synthesis performance of heat transfer and flow of three control strategies are evaluated. The numerical results show that the flow structure in boundary layer has been varied obviously for the effect of perturbation velocity and induced quasi-streamwise vortices emerging around the controlled zone. The results indicate that the vertical control strategy has the best synthesis performance of the three control strategies, which also has the least skin frication coefficient. The upstream and downstream strategies can improve the heat transfer performance, but the skin frication coefficient is higher than that with vertical control strategy.

13/03424 Hygrothermal behaviour of flat cool and standard roofs on residential and commercial buildings in North America

Moghaddaszadeh Ahrab, M. A. and Akbari, H. *Building and Environment*, 2013, 60, 1–11.

Installing roofs with high solar reflectance and high thermal emittance, known as 'Cool roofs,' are becoming increasingly popular because of their cooling energy saving potentials, cost effectiveness and sustainability. Lower surface temperature of cool roofs may affect the hygrothermal performance of roofing systems and hence their performance should be characterized in different climates. This study simulated the performance of several roofing systems including: typical, smart, and self-drying roofs for residential and commercial buildings. In addition, vented roofs with smart vapour retarders were proposed in very cold climate regions across North America. The authors also developed an algorithm to investigate the effect of snow on hygrothermal behaviour of dark and white roofs. Results showed that office buildings never experience moisture accumulation problems during the simulation period (5 years). In residential buildings, white typical roofing compositions with conventional vapour retarders experienced moisture accumulation problems in very cold cities such as Anchorage, Edmonton and St. John's. Using smart vapour retarder (smart roofs) or self-drying roofs helped to decrease risk of moisture accumulation. In these climates, adding a ventilated air space along with using smart vapour retarder eliminated the risk of moisture accumulation and prevented excessive oriented strand board moisture content. The risk of mould growth was significantly lowered in vented smart roofs. Simulating the effect of snow on the roofs for Anchorage, Montreal and Chicago showed that the hygrothermal performances of white roofs improved with snow accumulation on the roof.

13/03425 Interpretation of passive solar field data with EnergyPlus models: un-conventional wisdom from four sunspaces in Eugene, Oregon

Rempel, A. R. *et al. Building and Environment*, 2013, 60, 158–172.

Passive solar design in the Pacific Northwest relies greatly on traditions established elsewhere, resisting adoption of distinct regional practices despite growing evidence of their value. To promote progress toward climate-responsive design in the cloudy, rainy Cascadian corridor, and to gain insight into often-troubled passive solar performance in the region, energy transfer mechanisms underlying the measured performance of four Oregon sunspaces were investigated using EnergyPlus building models. Air, mass, globe, and soil temperatures, as well as relative humidity and incident solar radiation, were recorded at 10-min intervals in each sunspace from January through June, 2011; models incorporated geometric, material, occupancy, equipment, tree shading, and soil parameters relevant to energy gain and loss. Models were then validated by comparison with air and mass temperature data: all predicted 84–93% of measurement variability. Output showed that over half of all energy entering each sunspace originated as diffuse solar radiation, and that 60–70% of the total was transmitted through shallow-pitched roof glazing, in a pattern contrary to established belief. Similarly, much stored energy was lost through central rather than perimeter floor mass. Orientation exerted a minor effect on performance compared to other factors, particularly tree shading, while solar gain exceeded predictions of long-accepted methods by factors of two to three. Together, these results show that substantial revision of deep-rooted ideas and expectations will be needed to achieve high-performance passive solar heating in the Pacific Northwest.

13/03426 Large-scale experimental wind-driven rain exposure investigations of building integrated photovoltaics

Breivik, C. *et al. Solar Energy*, 2013, 90, 179–187.

Building integrated photovoltaics (BIPVs) are photovoltaic materials that replace conventional building materials in parts of the building envelopes, such as roofs or facades, i.e. the BIPV system serves dual purposes, as both a building envelope material and a power generator. Hence, it is important to focus on the building envelope properties of a BIPV system in addition to energy generation performance when conducting experimental investigations of BIPVs. The aim of this work was to illustrate challenges linked to the building envelope properties of a BIPV system, and to develop and evaluate relevant methods for testing the building envelope properties of BIPV systems. A sample roof area with two BIPV modules was built and tested in a turnable box for rain and wind tightness testing of sloping building surfaces with the aim of investigating the rain tightness of the BIPV system, and observing how it withstood wind-driven rain at large-scale conditions. The BIPV sample roof went through testing with run-off water and wind-driven rain with incremental pulsating positive differential pressure over the sample at two different inclinations. The BIPV sample roof was during testing constantly visually monitored, and various leakage points were detected. In order to prevent such water penetration, the steel fittings surrounding the BIPV modules should ideally be better adapted to the BIPV modules and constricted to some extent. It is however important to maintain a sufficient ventilation rate simultaneously.

13/03427 Microdroplet evaporation under increasing temperature conditions: experiments and modelling

Honnery, D. *et al. Fuel*, 2013, 105, 247–257.

This paper compares predictions of droplet evaporation processes of the widely used infinite conductivity model to experimental data of microdroplets evaporating under an increasing temperature condition. Near complete droplet histories of <100 μm sized droplets of dodecane, decane and nonane are convected at low Reynolds number through a reactor with a dominantly increasing gas temperature. This produces a prolonged heating period up to the peak temperature condition. This differs from previous studies which make use of a fixed temperature condition. Results show that while evaporation rates at the peak temperature condition are generally well predicted, during the prolonged expansion phase, evaporation rates are over predicted, while during the transitional heating phase, rates are under predicted. Similar to a steady state evaporation process, experimental evaporation rates were found to be almost linearly dependent on gas temperature once evaporation dominates expansion processes.

13/03428 Modeling and simulation of loss of the ultimate heat sink in a typical material testing reactor

El-Khatib, H. *et al. Annals of Nuclear Energy*, 2013, 51, 156–166.

A thermal–hydraulic model has been developed to simulate loss of the ultimate heat sink in a typical material testing reactor (MTR). The model involves three interactively coupled sub-models for reactor core, heat exchanger and cooling tower. The model is validated against PARET code for steady-state operation and verified by the reactor operation records for transients. Then, the model is used to simulate the thermal–hydraulic behaviour of the reactor under a loss of the ultimate heat sink event. The simulation is performed for two operation regimes: regime I representing 11 MW power and three cooling tower cells operated, and regime II representing 22 MW power and six cooling tower cells operated. In regime I, the simulation is performed for one, to three cooling tower cells failed while in regime II, it is performed for one to six cooling tower cells failed. The simulation is performed under protected conditions where the safety action called power reduction is triggered by reactor protection system to decrease the reactor power by 20% when the coolant inlet temperature to the core reaches 43 °C and scram is triggered if the core inlet temperature reaches 44 °C. The model results are analysed and discussed.

13/03429 Modelling and applications of annual energy–using simulation module of separated heat pipe heat exchanger

Zhu, D.-d. *et al. Energy and Buildings*, 2013, 57, 26–33.

Separate heat pipe heat exchanger (SHP heat exchanger) transports heat from the indoor air to the outdoor air by making use of the temperature difference. It consumes much less energy than split air-conditioners in telecommunication base stations (TBSs) because of no compressor. In this paper an annual energy-using simulation module of SHP was built up in the building energy simulation tool DeST. The SHP model was basing on the theoretical and experiment results of the heat transfer performance and the energy consumption. As the heat transfer quantity of SHP was interplayed with the indoor air temperature, the solution for the models of the dynamic thermal process in building and SHP heat exchanger was the key part, which was carried out by the coupling calculation. The reliability of SHP model and the coupling solution was verified by an empirical test. Finally, case study on the design of air-conditioning systems in TBSs was carried out to illustrate the engineering applications of SHP module.

13/03430 New kinds of energy-storing building composite PCMs for thermal energy storage

Biçer, A. and Sari, A. *Energy Conversion and Management*, 2013, 69, 148–156.

Energy storing-composite phase change materials (PCMs) are significant means of thermal energy storage in buildings. Although several building composite PCMs (BCPCMs) have been developed in recent years, the additional investigations are still required to enrich the diversity of BCPCMs for solar heating and energy conservation applications in buildings. For this purpose, this study focuses on the preparation, characterization and determination of 10 new kinds of BCPCMs. The BCPCMs were prepared by blending of liquid xylitol pentalaurate (XPL) and xylitol pentamyristate (XPM) esters with gypsum, cement, diatomite, perlite and vermiculite as supporting matrices. The scanning electron microscopy and Fourier transform infrared analysis showed that the ester compounds were adsorbed uniformly into the building materials due to capillary forces. The highest adsorption ratio of XPL ester into gypsum, cement, perlite, diatomite, and vermiculite were found to be 20, 19, 71, 52 and 40 wt%, respectively while it was found to be 22, 25, 66, 50 and 41 wt% for XPM ester, respectively. Differential scanning calorimetry results indicated that the melting temperatures and latent heat energy storage capacities of the prepared BCPCMs are in range of about 40–55 °C and 31–126 J/g, respectively. Thermogravimetric investigations showed that the BCPCMs had good thermal endurance even above their phase change temperatures. The BCPCMs exhibited almost same chemical and phase change characteristics after 1000 thermal cycling test. It can be also concluded that especially the BCPCMs perlite, vermiculite, diatomite content were found to better candidates for thermal energy storage applications in buildings due to the fact that they have relatively higher heat storage capacity.

13/03431 Numerical simulation of heat transfer deterioration phenomenon to supercritical water in annular channel

Liu, L. *et al. Annals of Nuclear Energy*, 2013, 53, 170–181.

As there is no phase change, the risk of boiling crisis can be excluded in super critical water-cooled reactors (SCWR). The heat transfer deterioration (HTD) phenomena, which result in an abnormal increase of wall temperature, however, may occur under some conditions. Therefore, it is important to understand the mechanism of HTD for keeping the temperature integrity of the fuel cladding. In this study, mechanisms of the influence of turbulence structure and fluid properties on HTD phenomena in annular channels at low mass flux and high mass flux were both investigated. The results showed that HTD at low mass flux is mainly caused by buoyancy effect and the variations of fluid properties, while at high mass flux HTD is due to the acceleration effect and the variations of fluid properties. Heat flux and the operating pressure also play important parts in HTD both at low mass flux and high mass flux.

13/03432 Numerical study on coupling phase change heat transfer performance of solar dish collector

Tao, Y. B. *et al. Solar Energy*, 2013, 90, 84–93.

In solar dish collector systems, the heat transfer process is a typical coupling heat transfer problem, where the heat conduction, radiation heat transfer, convection heat transfer and phase change heat transfer are coexisting. In this paper, a coupling model for Monte Carlo ray trace method (MCRTM) and finite volume method (FVM) was established to study the coupling heat transfer problem. Firstly, based on MCRTM, the non-uniform three-dimensional heat flux distributions on the solar dish receiver inner surface were obtained. Then the non-uniform heat flux distribution is used as the boundary condition to simulate the phase change and convection heat transfer process inside the heat transfer tube. The effects of the non-uniform heat flux distribution on temperature field in phase change material (PCM) were examined. The results show that the non-uniform heat flux on the tube surface will result in seriously non-uniform temperature distribution in PCM. Then the optimization analyses for the temperature distribution were performed according to the convection heat transfer process and heat conduction process respectively. The results show that in the studied conditions, when heat transfer fluid (HTF) velocity increases from 10 to 25 m/s, the maximum temperature difference in PCM will decrease from 781.2 to 497.8 K, which reduces about 36.3%. However, it will cause the heat storage capacity and HTF outlet temperature decrease. When the thermal conductivity increases from 3.8 to 19.0 $W m^{-1} K^{-1}$, the maximum temperature difference will decrease from 781.2 to 409.5 K, which reduces about 47.6%. And it will not result in HTF outlet temperature and heat storage capacity decreasing. So, enhancing the PCM thermal conductivity is an efficient method to achieve more uniform temperature distribution in PCM.

13/03433 On the proper integration of wood stoves in passive houses: investigation using detailed dynamic simulations

Georges, L. *et al. Energy and Buildings*, 2013, 59, 203–213.

Wood stoves are attractive for the space heating of passive houses. Nevertheless, there are still questions about their integration. First, the power oversizing of the current stoves and their long operating time may lead to unacceptable overheating. Secondly, it is also unclear how one stove can ensure the thermal comfort in the entire building. The paper investigates these aspects using detailed dynamic simulations applied to a detached house in Belgium. An 8 kW stove is assumed to be representative of the lowest available powers in the market. Results confirm that a large power modulation is important to prevent overheating. Opening the internal doors, a high building thermal mass and a heat emission dominated by radiation also reduce the overheating risk, but to a smaller extent. Besides, a single stove cannot enforce the thermal comfort during design weather conditions: a peak-load system is then needed. Using more standard conditions, a typical meteorological year, the stove can mainly perform the space heating but it then requires the internal doors inside the building to be opened. The temperature distribution between rooms is in fact dominated by the architectonic properties. Finally, the emission and distribution efficiency of the stove is also investigated.

13/03434 Optimal analysis of gas cooler and intercooler for two-stage CO_2 trans-critical refrigeration system

Li, W. *Energy Conversion and Management*, 2013, 71, 1–11.

Energy-based first law and exergy-based second law are both employed in the paper to assess the optimal design of gas cooler and intercooler for two-stage CO_2 refrigeration system. A simplified mathematical model of the air-cooled coil is presented and validated against experimental data with good accuracy. The optimum circuit length under the influence of frontal air velocity and deep rows is investigated first. Thereafter, designed coil with optimum circuit length is further evaluated within the two-stage refrigeration system. It is found out the optimum point using first law does not coincide with the point using second law in isolated component and the simulation results from isolated component by second law are closer to system analysis. Results show optimum circuit length is much bigger for gas cooler than intercooler and the influence on the length from variation of frontal air velocity and deep rows may be neglected. There does exist optimum frontal air velocity which will decrease with a larger number of deep rows.

13/03435 Optimal operation strategy of the hybrid heating system composed of centrifugal heat pumps and gas boilers

Li, F. *et al. Energy and Buildings*, 2013, 58, 27–36.

Centrifugal heat pump has to be coupled with a gas boiler to supply high temperature water in a radiator heating system. Regarding to hybrid heating system (HHS), operation strategy has significant impact on its annual energy consumption and cost. In this paper, the optimal operation strategy of the HHS composed of sewage-source centrifugal heat pumps and gas boilers was analysed. First, the performance models of the system components, including terminal radiator, heat pump, gas boiler and water pump were established respectively. Secondly, with the aim at minimizing the operating cost of the system the optimal operation strategy of the system was analysed. Finally, the annual operating cost and energy consumption of the HHS were compared with these of coal-fired boiler heating system. The results indicate that the HHS offers significant reductions in energy consumption (45.2%) and operating cost (13.5%). Therefore, the HHS has a promising application prospect, the results provide reference for scientific operation of the HHS.

13/03436 Optimization of HVAC systems for distributed generation as a function of different types of heat sources and climatic conditions

Marini, D. *Applied Energy*, 2013, 102, 813–826.

This paper describes the results from a performance comparison of different types of HVAC systems in a low energy residential building. There were five different HVAC systems which were investigated and evaluated: ground coupled heat pumps (GCHP); ground water heat pumps (GWHP); air-to-water heat pumps (AWHP); air-to-air heat pumps (AAHP); and boiler & split (B&S) systems applied respectively for heating and cooling seasons. These HVAC systems were implemented in one residential-complex which consisted of a three-story block subdivided into 15 apartments with total floor area of 1050 m^2. Year-round dynamic simulations were carried out using Energy Plus based on three different climatic conditions from northern, central and southern Italy. The climates of cities Milan, Rome and Palermo were used respectively in order to estimate potential energy savings among HVAC systems for each site location. It was found that in Milan, AAHP & AWHP heat pump systems save 14.8% and 23.3% primary energy respectively compared to the B&S system, while GCHP and GWHP systems save 59.6% and 62.6% respectively. A techno-economic analysis for a 20-year period was also carried out for each specific case. It was observed that the GWHP case becomes economically feasible after 9 years with respect to other cases for the Milan case study.

13/03437 Peak load shifting control using different cold thermal energy storage facilities in commercial buildings: a review

Sun, Y. *et al. Energy Conversion and Management*, 2013, 71, 101–114.

For decades, load shifting control, one of most effective peak demand management methods, has attracted increasing attentions from both researchers and engineers. Different load shifting control strategies have been developed when diverse cold thermal energy storage facilities are used in commercial buildings. The facilities include building thermal mass, thermal energy storage system and phase change material. Little study has systematically reviewed these load shifting control strategies and therefore this study presents a comprehensive review of peak load shifting control strategies using these thermal energy storage facilities in commercial buildings. The research and applications of the load shifting control strategies are presented and discussed. The further efforts needed for developing more applicable load shifting control strategies using the facilities are also addressed.

13/03438 Performance analysis of a diffusion absorption refrigeration cycle working with TFE–TEGDME mixture

Long, Z. *et al. Energy and Buildings*, 2013, 58, 86–92.

The binary mixture of tetraethylene glycol dimethyl ether (TFE-TEGDME) has good thermophysical properties and been investigated by many absorption chiller and heat pump researchers. However, few studies have been reported on the diffusion absorption refrigeration (DAR) system using TFE–TEGDME as the working fluid. This study numerically investigates the potential of TFE–TEGDME used in the DAR system with two cooling mediums, namely water (32 °C) and air (35 °C). It is found that with the absorber effectiveness of 0.8, the optimum generation temperature for the air-cooled TFE–TEGDME DAR system is around 170 °C, and the corresponding coefficient of performance (COP) is up to 0.45. In comparison, the performance of the water-cooled system is better with a lower optimum generation temperature around 130 °C and a higher COP reaching 0.56. Parametric studies are also conducted to analyse the effects of the cooling medium, generation temperature, evaporation temperature and absorber effectiveness on the system performance. Finally, the performance of the TFE–TEGDME and NH_3–H_2O DAR cycles is compared in terms of the COP and circulation ratio. Overall, it can be concluded that the TFE–TEGDME mixture is a good working fluid for the DAR cycle.

13/03439 Performance analysis of the air-conditioning system in Xi'an Xianyang international airport

Zhang, T. *et al. Energy and Buildings*, 2013, 59, 11–20.

Reducing the energy consumption of air-conditioning systems is becoming increasingly important. This paper focuses on the air-conditioning system in terminal 3 of Xi'an Xianyang international airport, the first airport terminal to adopt radiant cooling in China. In the large spaces of this airport terminal, a temperature and humidity independent control (THIC) system has been adopted instead of a conventional nozzle air supply method, which significantly reduces the energy consumption of the air supply. The radiant floor is the main mechanism for indoor temperature control, while a liquid desiccant outdoor air processor combined with displacement ventilation is responsible for humidity control. Ice storage is adopted to reduce operating costs, and the supplied chilled water temperature can be as low as 3 °C. This paper examines the performance of the THIC system in detail. The indoor environment is determined through measurements to be comfortable, and the on-site performances of key components in both the airport terminal and the cooling plant are investigated. The outdoor air processor supplies air of appropriate temperature and humidity ratio; two kinds of radiant floors are used for temperature control, both with measured cooling capacities of about 30–40 W/m^2; and the energy efficiency ratio of the cooling plant is 2.62.

13/03440 Performance of radiant cooling surfaces with respect to energy consumption and thermal comfort

Oxizidis, S. and Papadopoulos, A. M. *Energy and Buildings*, 2013, 57, 199–209.

The intensive use of electrically driven vapour compressor air conditioning is accompanied by an analogous environmental impact and the imposition of a severe stress on the electric grid. Still, the decarbonization of the latter, by the increased utilization of renewable energy sources, and the implementation of smart grids could help in overcoming those issues, if a different approach in thermal energy storage and thermal comfort in the cooling of buildings can be achieved. Hydronic radiant building surfaces address those issues providing thermal comfort by cooling directly the building and the people, utilizing high temperature cooling water, that increases the efficiency of cooling systems, while they present the feature of thermal energy storage embedded in their construction. The present study compares radiant and convection systems with respect to final energy consumption and thermal comfort in a test cell representing an office room. The results highlight the issues of proper control of radiant systems in order to take full advantage of their specific features and of the appropriate evaluation of thermal comfort conditions provided by those systems.

13/03441 Reflective coatings for interior and exterior of buildings and improving thermal performance

Joudi, A. *et al. Applied Energy*, 2013, 103, 562–570.

The importance of reducing building energy usage and thriving for more energy efficient architectures, has nurtured creative solutions and smart choices of materials in the last few decades. Among those are optimizing surface optical properties for both interior and exterior claddings of the building. Development in the coil-coating steel industries has now made it possible to allocate correct optical properties for steel clad buildings with improved thermal performance. Although the importance of the exterior coating and solar gain are thoroughly studied in many literatures, the effect of interior cladding are less tackled, especially when considering a combination of both interior and exterior reflective coatings. This paper contemplates the thermal behaviour of small cabins with reflective coatings on both interior and exterior cladding, under different conditions and climates with the aim to clarify and point out to the potential energy saving by smart choices of clad coatings.

13/03442 Review of cold storage materials for subzero applications

Li, G. *et al. Energy*, 2013, 51, 1–17.

This paper reviews the recent development of available cold storage materials for subzero applications. According to the type of a storage medium and the way of the storage medium is used, phase change material (PCM) storage and sorption storage are introduced separately. Eutectic water–salt solutions and non-eutectic water–salt solution PCMs are discussed from thermal and physicochemical properties such as fusion heat, thermal conductivity, phase separation, supercooling, corrosion, flammability, etc. Related solutions for issues of such PCMs are offered. Microencapsulated PCMs are introduced as they have an excellent heat transfer performance to the surroundings because of the large surface per volume of the capsules and the excellent cycling stability due to the restricted phase separation in microscopic distances. PCMs with nanoparticle additives are also discussed as they have higher thermal conductivity for better storage process. Absorption and adsorption storages are mainly discussed for their working pairs, heat transfer enhancement and system performance improvement aspects. Relevant perspective technologies are discussed for further work.

13/03443 Review of passive PCM latent heat thermal energy storage systems towards buildings' energy efficiency

Soares, N. *et al. Energy and Buildings*, 2013, 59, 82–103.

This paper aims to explore how and where phase change materials (PCMs) are used in passive latent heat thermal energy storage (LHTES) systems, and to present an overview of how these construction solutions are related to building's energy performance. A survey on research trends are firstly presented followed by the discussion of some physical and theoretical considerations about the building and the potential of integrating PCMs in construction elements. The different types of PCMs and main criteria that govern their selection are reviewed, as well as the main methods to measure PCMs' thermal properties, and the techniques to incorporate PCMs into building elements. The numerical modelling of heat transfer with phase-change and heat transfer enhanced techniques are discussed, followed by a review of several passive LHTES systems with PCMs. Studies on dynamic simulation of energy in buildings incorporating PCMs are reviewed, mainly those supported by EnergyPlus, ESP-r and TRNSYS software tools. Lifecycle assessments, both environmental and economic are discussed. This review shows that passive construction solutions with PCMs provide the potential for reducing energy consumption for heating and cooling due to the load reduction/shifting, and for increasing indoor thermal comfort due to the reduced indoor temperature fluctuations.

13/03444 Rule-based Mamdani-type fuzzy modeling of heating and cooling performances of counter-flow Ranque–Hilsch vortex tubes with different geometric construction for steel

Berber, A. *et al. Energy*, 2013, 51, 297–304.

In this study, heating and cooling performances of counter-flow Ranque–Hilsch vortex tubes (RHVT) were experimentally investigated and modelled with a RBMTF (Rule-Based Mamdani-Type Fuzzy) modelling technique. Input parameters (ξ, L/D) and output parameters ΔT_h, ΔT_c were described by RBMTF if-then rules. Eighty-one experimental data sets were used in the training step. Numerical parameters of input and output variables were fuzzificated as linguistic variables: very very low (L1), very low (L2), low (L3), negative medium (L4), medium (L5), positive medium (L6), high (L7), very high (L8) and very very high (L9) linguistic classes. R^2 for the ΔT_h was found to be 99.60% and R^2 for the ΔT_c was 99.80%. The actual values and RBMTF results indicated that RBMTF can be successfully used for the determination of heating and cooling performances of counter-flow RHVT with different geometric constructions for steel.

13/03445 Study on the effect of shape-stabilized phase change materials on spacecraft thermal control in extreme thermal environment

Wu, W.-f. *et al. Energy Conversion and Management*, 2013, 69, 174–180.

In space, the emergencies such as short-term high heat flux is prone to cause spacecraft thermal control system faults, resulting in temperature anomalies of electronic equipment of the spacecraft and even failures in them. In order to protect the spacecraft attacked by the high energy, a new guard method is proposed. A shape-stabilized phase change material (PCM), which has high thermal conductivity and does not require being tightly packaged, is proposed to be used on the spacecraft. To prove the feasibility of using the material on spacecraft attacked by high energy, the thermal responses for spacecraft with shape-stabilized PCM are investigated in situations of normal and short-term high heat flux, in contrast to that with conventional thermal control system. The results indicate that the shape-stabilized PCM can effectively absorb the heat to prevent the thermal control system faults when the spacecraft's outer heat flux changes dramatically and has no negative effect on spacecraft in normal heat flux. Additionally the effect of thermal conductivity of PCM on its application effectiveness is discussed.

13/03446 The estimation of energy efficiency for hybrid refrigeration system

Gazda, W. and Koziol, J. *Applied Energy*, 2013, 101, 49–57.

The concept of the air blast-cryogenic freezing method is based on an innovative hybrid refrigeration system with one common cooling space. The hybrid cooling system consists of a vapour compression refrigeration system and a cryogenic refrigeration system. The prototype experimental setup for this method on the laboratory scale is discussed. The application of the results of experimental investigations and the theoretical–empirical model makes it possible to calculate the cooling capacity as well as the final and primary energy use in the hybrid system. The energetic analysis has been carried out for the operating modes of the refrigerating systems for the required temperatures inside the cooling chamber of −5, −10 and −15 °C. For the estimation of the energy efficiency the coefficient of performance and the primary energy ratio for the hybrid refrigeration system are proposed.

13/03447 The structure analysis of ITER cryostat based on the finite element method

Liang, C. *et al. Fusion Engineering and Design*, 2013, 88, (1), 42–45.

In the ITER project the cryostat is one of the most important components. Cryostat shall transfer all the loads that derive from the TOKAMAK inner basic machine, and from the cryostat itself, to the floor of the TOKAMAK pit (during the normal and off-normal operational regimes, and at specified accidental conditions). This paper researches the dynamic structure strength of the ITER cryostat during the operation of TOKAMAK. First, the paper introduces the types of loads and the importance of every type load to the research. Then it gives out the method of building model and principle of simplified model, boundary conditions and the way of applying loads on the cryostat. Finally the author discussed the analysis result and the strength questions of cryostat, also, the author pointed out the opinions according to the analysis results.

13/03448 The use of the first and of the second order phase magnetic transition alloys for an AMR refrigerator at room temperature: a numerical analysis of the energy performances

Aprea, C. *et al. Energy Conversion and Management*, 2013, 70, 40–55.

The magnetic refrigeration is a new highly efficient and environmentally protective technology, which could be an actual solution for the typical problems of the vapour compression systems. The core of a magnetic refrigerator system is the active magnetic regenerator

(AMR). It is a special kind of thermal regenerator made of magnetic material which works both as a refrigerating medium and as a heat regenerating medium. The performance of an AMR system strongly depends on the magnetocaloric effect of the magnetic material used to build the regenerator. In the present paper, a model to simulate the thermal behaviour of an AMR has been introduced for predicting the performance of an AMR refrigerator system. Different magnetic materials have been considered as refrigerant: pure gadolinium, second order phase magnetic transition binary rare earth alloys (SOMT) and first order phase magnetic transition alloys (FOMT). The SOMT are Gd_xDy_{1-x} and Gd_xTb_{1-x} whereas the FOMT are $Gd_5(Si_xGe_{1-x})_4$ and $MnAs_{1-x}Sb_x$. The magnetocaloric behaviour of gadolinium can be correctly predicted by the Weiss molecular field theory. This approach can be generalized for binary alloys with a second order phase transition. The behaviour of the $MnAs_{1-x}Sb_x$ alloys is described by means of a model based on the phenomenological approach of Bean Rodbell. Interpolation of empirical data is utilized for the evaluation of the magnetocaloric effect of $Gd_5(Si_xGe_{1-x})_4$ alloys. With this model, the refrigeration capacity, the power consumption and consequently the coefficient of performance of the cycle can be predicted. The results of the simulation clearly show that $Gd_5(Si_xGe_{1-x})_4$ is the best magnetic material with a COP that is always greater than that of a traditional vapour compression plant in the same operating conditions (from a minimum of +40% to a maximum of +62%).

13/03449 Thermal impedance spectroscopy – a method for the thermal characterization of high power battery cells

Fleckenstein, M. *et al. Journal of Power Sources*, 2013, 223, 259–267.

A new approach of thermal impedance spectroscopy (TIS) is introduced for thermal characterization of battery cells. It examines the transfer behaviour between internal heat generation and resulting battery surface temperature in the frequency domain. Compared to previously published TIS methods the internal heat generation forced by electrical operation can be determined without any previous knowledge or assumptions on the electric/electrochemical behaviour of the battery cell. The complete procedure is demonstrated by the TIS-application on a cylindrical high-power Li-ion cell. By the use of a thermal battery model, its theoretical transfer function can be fitted to the TIS measurement results in the Nyquist plot. Consequently, the specific heat capacity and the heat conductivity of the cell's jelly roll can be derived. A comparison of the exemplary operated TIS to conventional thermal characterization methods shows a difference of 5% in the heat capacity and 12% in the heat conductivity determination. Future improvements on the experimental setup are suggested in order to reach a higher measurement accuracy and additionally, the systematic advantages of the easy to operate and non-destructive TIS-method are presented.

13/03450 Thermal modeling and operating tests for a gas-engine driven heat pump working as a water heater in winter

Yang, Z. *et al. Energy and Buildings*, 2013, 58, 219–226.

Gas-engine driven heat pump (GEHP) working as water heater has higher energy utilization efficiency and can reduce more environmental pollution than gas-fired (oil-fired, coal-fired) boiler and electric motor driven heat pump (EHP). In this study, a thermal model of a GEHP system working as water heater was established, and the performances (heating capacity, coefficient of performance (COP) and primary energy ratio (PER) of the GEHP system were also studied both by simulation and experiment. The results showed that the heating capacity increased with the increase of the rotary speed and water flow rate, but decreased with the increase of the hot water temperature. The COP and PER increased with the increase of the water flow rate, but decreased with the increase of the rotary speed and hot water temperature. The simulation results agreed well with experimental data. The defrost time of the GEHP system was also studied by experiment, the results showed that the defrost time of both using waste heat recovered and reverse cycle defrost (RCD) was the shortest among the three defrost methods used in this paper.

13/03451 Thermal performance analysis of a solar water heating system with heat pipe evacuated tube collector using data from a field trial

Ayompe, L. M. and Duffy, A. *Solar Energy*, 2013, 90, 17–28.

This paper presents an analysis of the thermal performance of a solar water heating system with heat pipe evacuated tube collector using data obtained from a field trial installation over a year in Dublin, Ireland. An automated sub-system was developed and incorporated to control the hot water draw-offs and electric immersion heater to mimic the operation of solar water heating systems in domestic dwellings. The maximum recorded collector outlet fluid temperature was 70.3 °C while the water temperature at the bottom of the hot water tank was 59.5 °C. The annual average daily energy collected was $20.4\,\mathrm{MJ\,d^{-1}}$, energy delivered by the solar coil was $16.8\,\mathrm{MJ\,d^{-1}}$, supply pipe loss was $3.6\,\mathrm{MJ\,d^{-1}}$, solar fraction was 33.8%, collector efficiency was 63.2% and system efficiency was 52.0%. Reducing the supply pipe losses which represented 17.7% of energy collected and 21.5% of energy delivered to the hot water tank, and developing a better pump control strategy for heavily overcast and intermittent cloud covered days could result in system improvement.

13/03452 Thermal–hydraulic modeling of nanofluids as the coolant in VVER-1000 reactor core by the porous media approach

Zarifi, E. *et al. Annals of Nuclear Energy*, 2013, 51, 203–212.

The aim of this study was to perform a thermal–hydraulic analysis of nanofluids as the coolant in the VVER-1000 reactor core using the porous media approach. Water-based nanofluids containing various volume fractions of Al_2O_3 and TiO_2 nanoparticles were analysed. The addition of different types and volume fractions of nanoparticles were observed to have several effects on reactor thermal–hydraulic characteristics. Based on a porous media approach, each fuel assembly was modelled and divided into a network of volumes or lumped regions, each of which was characterized by a volume average parameter. The conservation equations were discretized by the finite volume method and the obtained non-linear algebraic equations were solved by numerical methods using visual FORTRAN language. Finally, the nanofluids analysis was compared with an analysis of pure water. To validate the applied approaches applied in this study, the results of the model and COBRA-EN code were compared for pure water. The achieved results show that the temperature of the coolant increases with the concentration of nanoparticles. Therefore, the coolant flow rate can be reduced due to the higher heat transfer coefficient of nanofluids compared to pure water.

13/03453 Transient simulation code development of primary coolant system of Chinese experimental fast reactor

Cui, M. *et al. Annals of Nuclear Energy*, 2013, 53, 158–169.

Chinese experimental fast reactor (CEFR) is a 25 MWe sodium-cooled, pool-type reactor, which was built at the China Institute of Atomic Energy in Beijing as the forerunner to the first-stage of Chinese fast reactor development plans. In order to understand the response of the primary coolant system (PCS) to various transients and train the operators a dynamic model using basic energy and momentum equations was developed with some assumptions. Heat transfer models for reactor core and intermediate heat exchanger were also included. Subroutines were developed to calculate the thermal properties, friction coefficients and heat transfer coefficients of liquid sodium. Gear's method was applied to solve the dynamic model. A transient analysis code named THPCS (thermal–hydraulic code of PCS) was developed and is independent of the design and safety analysis codes. Three typical events, such as loss of one primary pump, unprotected transient overpower and accidental closure of primary pump check valves were chosen and investigated. The prediction results of the code agree well with those of the final safety analysis report of CEFR. A fourth postulated accident, station blackout without scram and loss of all heat sink, was also analysed to show the ability of the code, which is more serious than the former. The transient simulation code developed in this paper will be useful for the safety operation of CEFR.

11 ENGINES

Power generation and propulsion, electrical vehicles

13/03454 A further evaluation of the mixing controlled direct chemistry (MCDC) combustion model for diesel engine combustion using large eddy simulation

Zhang, Y. and Rutland, C. J. *Fuel*, 2013, 105, 272–282.

The local mixing effect at sub-grid scale (SGS) is explored using large eddy simulation (LES) turbulence model with a mixing controlled direct chemistry (MCDC) model. The MCDC model is developed using the computation of chemical kinetics, thermo-chemical equilibrium state and SGS mixing effects by combining a mixing time scale and a kinetic time scale with the integration of direct chemistry solver (DCS) solutions. The mixing time scale is based on the SGS scalar variance and SGS scalar dissipation rate. The kinetic time scale is based on thermal–chemical equilibrium state and the kinetic reaction rate. These two time scales have been previously evaluated in experiments and computations, showed reasonable quantifications of local mixing and kinetic progress, which improved accuracy of combustion modelling. In this study, the conventional diffusion-type operating conditions are represented by a Caterpillar 3401^{TM} single cylinder oil test engine (SCOTE). The cylinder-averaged results are compared between the DCS model, MCDC model and 'Kong-Reitz' model. A grid dependence study for the MCDC model on a baseline grid and a coarse grid is performed. The mixing time scale and kinetic time scale analysis for the MCDC model and 'Kong-Reitz' model is provided to investigate the differences in predictions. Compared to the DCS model and 'Kong-Reitz' model, the MCDC model shows improved capability in modelling mixing effects at the SGS level, which is represented by the improved prediction of combustion phasing and good matching with experimental results.

13/03455 An analysis of spray development with *iso*-octane, *n*-pentane, gasoline, ethanol and *n*-butanol from a multi-hole injector under hot fuel conditions

Aleiferis, P. G. and van Romunde, Z. R. *Fuel*, 2013, 105, 143–168.

High-pressure multi-hole injectors for direct-injection spark-ignition engines offer some great benefits in terms of fuel atomization, as well as flexibility in fuel targeting by selection of the number and angle of the nozzle's holes. However, very little data exist for injector-body temperatures representative of engine operation with various fuels, especially at low-load conditions with early injection strategies that can also lead to phase change due to fuel flash boiling upon injection. The challenge is further complicated by the predicted fuel stocks which will include a significant bio-derived component presenting the requirement to manage fuel flexibility. The physical/chemical properties of bio-components, like various types of alcohols, can differ markedly from gasoline and it is important to study their effects in direct comparison to liquid hydrocarbons. This work outlines results from an optical investigation (high-speed imaging and droplet sizing) into the effects of fuel properties, temperature and pressure conditions on the extent of spray formation. Specifically, gasoline, *iso*-octane, *n*-pentane, ethanol and *n*-butanol were tested at 20, 50, 90 and 120 °C injector body temperatures for ambient pressures of 0.5 bar and 1.0 bar in order to simulate early homogeneous injection strategies for part-load and wide open throttle engine operation; some test were also carried out at 180 °C, 0.3 bar. Droplet sizing was also performed for gasoline, *iso*-octane and *n*-pentane using phase Doppler and laser diffraction techniques in order to understand the effects of low- and high-volatility components on the atomization of the multi-component gasoline. The boiling points and distillation curves of all fuels, their vapour pressures and bubble points, as well as density, viscosity and surface tension were obtained and the Reynolds, Weber and Ohnesorge numbers were considered in the analysis.

13/03456 An approximate expression for part-load performance of a microturbine combined heat and power system heat recovery unit

Rachtan, W. and Malinowski, L. *Energy*, 2013, 51, 146–153.

An approximate expression for the heat transfer rate of a heat recovery unit (HRU) fed by the exhaust gas exiting a microturbine operating at part-load is developed. The proposed expression can be used for various microturbine–HRU sets if the appropriate values of coefficients are used. The independent variables in this expression are limited to: the microturbine electrical power output, the circulating water mass flow rate, and the circulating water inlet temperature. By the method of non-linear regression the coefficients of the approximate expression are determined for two types of microturbines and five types of HRUs. The developed expression greatly facilitates the prediction of available thermal power. Thus it can be useful in mathematical modelling of cogeneration plants based on microturbines as well as at the design and operation of such systems.

13/03457 An experimental study on performance and emissions of a small SI engine generator set fuelled by hydrous ethanol with high water contents up to 40%

Munsin, R. *et al. Fuel*, 2013, 106, 586–592.

This study focused on the effects of the use of hydrous ethanol with high water contents up to 40% on the performance and emissions of a small spark ignition engine for a generator. The effects of loads and ethanol water contents on engine performance and emissions were investigated. The results show that for ethanol with 5% water content (Eh95) at constant engine speed of 3600 rpm and at stoichiometric air–fuel ratio, CO and $HC + NO_x$ emissions after the catalytic converter were lower than the EPA limit model year 2011 tested under same load conditions of California exhaust emission standards and test procedures for 2005 and later small off-road engines. However for emissions before the catalytic converter, only CO is lower than the EPA limit model year 2011, while $HC + NO_x$ is higher. Increasing loads increased the overall efficiency, while BSFC, HC, formaldehyde and acetaldehyde emissions decreased. Increasing water content at constant load decreased overall efficiency and NO_x emission, while BSFC, HC, CO, formaldehyde and acetaldehyde emissions were increased. A catalytic converter is required to reduce the regulated and unregulated emissions when hydrous ethanol is used for a small SI engine generator set.

13/03458 Characterization of a radial turbocharger turbine in pulsating flow by means of CFD and its application to engine modeling

Galindo, J. *et al. Applied Energy*, 2013, 103, 116–127.

This paper presents a numerical study analysing the effect of pulsating flow in a variable geometry radial inflow turbine. The turbine behaviour is analysed under isentropic pulses, which are similar to those created by a rotating disk in a turbocharger test rig. Three different pulse frequencies (50, 90 and 130 Hz) and two pulse amplitudes (100 and 180 kPa) were considered. Turbine flow was studied throughout the pressure pulsation cycles in a wide range of off-design operating conditions, from low pressure ratio flow detachment to high pressure ratio choked flow. An overall analysis of the phasing of instantaneous mass flow and pressure ratio was first performed and the results show the non-quasi-steady behaviour of the turbine as a whole as described in the literature. However, the analysis of the flow in the different turbine components independently gives a different picture. As the turbine volute has greater length and volume than the other components, it is the main source of non-quasi-steadiness of the turbine. The stator nozzles cause fewer accumulation effects than the volute, but present a small degree of hysteretic behaviour due to flow separation and reattachment cycle around the vanes. Finally, the flow in the moving rotor behaves as quasi-steady, as far as flow capacity is concerned, although the momentum transfer between exhaust gas and blades (and thus work production and thermal efficiency) is affected by a hysteretic cycle against pressure ratio, but not if the blade speed ratio is considered instead. A simple model to simulate the turbine stator and rotor is proposed, based on the results obtained from computational fluid dynamics computations.

13/03459 Combustion and performance characteristics of CI (compression ignition) engine running with biodiesel

Tesfa, B. *et al. Energy*, 2013, 51, 101–115.

Biodiesel is one of the alternative fuels which is renewable and environmentally friendly and can be used in diesel engines with little or no modifications. In this study, experimental investigations were carried out on the effects of biodiesel types, biodiesel fraction and physical properties on the combustion and performance characteristics of a compression ignition engine. The experimental work was conducted on a four-cylinder, four-stroke, direct injection and turbo-charged diesel engine by using biodiesel of waste oil, rapeseed oil and corn oil and normal diesel. Based on the measured parameters, detailed analyses were carried out on cylinder pressure, heat release rate and brake specific fuel consumption (BSFC). It has been seen that the biodiesel types do not result in any significant differences in peak cylinder pressure and BSFC. The results also clearly indicate that engines running with biodiesel have slightly higher in-cylinder pressure and heat release rate than engines running with normal diesel. The BSFC for engines running with neat biodiesel was higher than engines running with normal diesel by up to 15%. It is also noticed that the physical properties of the biodiesel affect significantly engine performance.

13/03460 Effects of intake flow and coolant temperature on the spatial fuel distribution in a direct-injection gasoline engine by PLIF technique

Kim, S. *et al. Fuel*, 2013, 106, 737–748.

The spatial fuel distributions of the homogeneous and stratified charge of a high pressure six-hole injector were examined in a single cylinder optical direct injection spark ignition (DISI) engine. The effects of in-cylinder charge motion, fuel injection pressure and coolant temperature were investigated using a planar laser induced fluorescence (PLIF) technique. It was found that in the case of homogeneous charge mode, early injection in the intake stroke generated similar fuel distributions at the crank angle of 12° BTDC regardless of the in-cylinder air motion at the coolant temperature of 90 °C. In the case of stratified charge mode, the in-cylinder tumble flow played more effective role in mixture preparation than the swirl flow during the compression stroke; and the increase of the coolant temperature improved fuel evaporation; but the increase of the fuel supplying pressure could not change the pattern of the fuel vapour distribution against the expectation.

13/03461 Energy and exergy analysis on gasoline engine based on mapping characteristics experiment

Fu, J. *et al. Applied Energy*, 2013, 102, 622–630.

In order to evaluate the energy utilization efficiency of gasoline engine and predict the recovery potential for waste heat energy, energy distribution and waste heat energy characteristics of a naturally aspirated gasoline engine have been studied by combining the methods of energy and exergy analysis. During the research processes, engine energy balance tests were conducted under mapping characteristics, and the parameters required for calculating the energy balance and exergy balance were measured. On this basis, waste heat recovery potential and gasoline engine total exergy efficiency were studied by using the method of exergy analysis. Research results show: at low-speed and low-load, waste heat energy mainly focuses on cooling water;

at high-speed and high-load, exhaust gas energy is larger than cooling water energy not only in quantity, but also in exergy percentage and exergy efficiency; the highest exhaust gas exergy efficiency appears in high-speed and high-load area, while the highest cooling water exergy efficiency appears in low-speed and low-load area; theoretically, total fuel efficiency of this gasoline engine can be nearly improved by a time through waste heat recovery, and the maximum total fuel efficiency can reach 60%.

13/03462 Inter-cycle variability of in-cylinder pressure parameters in an ethanol fumigated common rail diesel engine

Bodisco, T. and Brown, R. J. *Energy*, 2013, 52, 55–65.

The effects of ethanol fumigation on the inter-cycle variability of key in-cylinder pressure parameters in a modern common rail diesel engine have been investigated. Specifically, maximum rate of pressure rise, peak pressure, peak pressure timing and ignition delay were investigated. A new methodology for investigating the start of combustion was also proposed and demonstrated – which is particularly useful with noisy in-cylinder pressure data as it can have a significant effect on the calculation of an accurate net rate of heat release indicator diagram. Inter-cycle variability has been traditionally investigated using the coefficient of variation. However, deeper insight into engine operation is given by presenting the results as kernel density estimates; hence, allowing investigation of otherwise unnoticed phenomena, including: multi-modal and skewed behaviour. This study has found that operation of a common rail diesel engine with high ethanol substitutions (>20% at full load, >30% at three quarter load) results in a significant reduction in ignition delay. Further, this study also concluded that if the engine is operated with absolute air to fuel ratios (mole basis) less than 15, the inter-cycle variability is substantially increased compared to normal operation.

13/03463 Numerical evaluation of the potential of late intake valve closing strategy for diesel PCCI (premixed charge compression ignition) engine in a wide speed and load range

Jia, M. *et al. Energy*, 2013, 51, 203–215.

A full-engine-cycle multidimensional model was applied to investigate the effect of late intake valve closing (IVC) on combustion and emission characteristics in a diesel premixed charge compression ignition (PCCI) engine in a wide speed and load range. The results indicate that the in-cylinder swirl ratio and turbulence kinetic energy are significantly enhanced with increased engine speed, while only swirl ratio is slightly affected by the variation in IVC timing. In PCCI combustion mode, ignition timing varies with engine load and speed, and late IVC strategy leads to a noticeable delay in ignition timing by decreasing the effective compression ratio over all the operating range. Late IVC is a very effective approach for reduction of NO_x emissions in the whole operating range, but the benefit of soot reduction with late IVC only locates in the low-to-medium load range. Moreover, it is found that indicated specific fuel consumption is effectively decreased with the employment of late IVC strategy in the medium-to-high load and low-to-medium speed range. Overall, by delaying ignition phasing and decreasing combustion temperature from late IVC timing, the high NO_x emissions at medium load, and low fuel efficiency at low speed can be avoided for PCCI combustion.

13/03464 On the exergetic effectiveness of combined-cycle engines for high speed propulsion

Fernández-Villacé, V. and Paniagua, G. *Energy*, 2013, 51, 382–394.

Air-breathing engines are utilized in the hypersonic regime through thermal integration of the fuel into the propulsive cycle, which improves the efficiency by recovering thermal energy from the freestream and the aeroshell. The classical efficiency figures based on first principle analyses are inaccurate performance indicators of the resulting combined cycle. Instead, this paper deduced the engine thermal and airframe transfer effectiveness based on thermodynamic availability, related to the overall losses of the thermally integrated vehicle for a given mission. The engine overall effectiveness, derived from the propulsive efficiency and the engine thermal effectiveness, was found to be a generalization of the Bréguet equation. The developed methodology was demonstrated in a combined cycle engine operating at flight speeds from Mach 2.5 to 5. In particular, the propulsive efficiency, thermal effectiveness, total loss and subcomponent losses were evaluated using the common framework of thermodynamic availability.

13/03465 Optimal sizing of plug-in fuel cell electric vehicles using models of vehicle performance and system cost

Xu, L. *et al. Applied Energy*, 2013, 103, 477–487.

This paper presents an optimal sizing method for plug-in proton exchange membrane (PEM) fuel cell and lithium-ion battery (LIB) powered city buses. A theoretical model is proposed describing the relationship between components' parameters and vehicle performance. Analysis results show that within the working range of the electric motor, the maximal velocity and driving distance are influenced linearly by the parameters of the components, e.g. fuel cell efficiency, fuel cell output power, stored hydrogen mass, vehicle auxiliary power, battery capacity, and battery average resistance. Moreover, accelerating time is also linearly dependent on the abovementioned parameters, except of those of the battery. Next, the authors attempt to minimize fixed and operating costs by introducing an optimal sizing problem that uses as constraints the requirements on vehicle performance. By solving this problem, they attain several optimal sizing rules. Finally, these rules are used to design a plug-in PEM fuel cell city bus and present performance results obtained by on-road testing.

Hybrid engine systems

13/03466 Cost-effectiveness of plug-in hybrid electric vehicle battery capacity and charging infrastructure investment for reducing US gasoline consumption

Peterson, S. B. and Michalek, J. J. *Energy Policy*, 2013, 52, 429–438.

Federal electric vehicle (EV) policies in the USA currently include vehicle purchase subsidies linked to EV battery capacity and subsidies for installing charging stations. The authors assess the cost-effectiveness of increased battery capacity vs non-domestic charging infrastructure installation for plug-in hybrid electric vehicles as alternate methods to reduce gasoline consumption for cars, trucks, and SUVs in the US. They found across a wide range of scenarios that the least-cost solution is for more drivers to switch to low-capacity plug-in hybrid electric vehicles (short electric range with gasoline backup for long trips) or gasoline-powered hybrid electric vehicles. If more gasoline savings are needed per vehicle, non-domestic charging infrastructure installation is substantially more expensive than increased battery capacity per gallon saved, and both approaches have higher costs than US oil premium estimates. Cost effectiveness of all subsidies are lower under a binding fuel economy standard. Comparison of results to the structure of current federal subsidies shows that policy is not aligned with fuel savings potential, and issues and alternatives are discussed.

13/03467 Design, simulation, and prototype production of a through the road parallel hybrid electric motorcycle

Asaei, B. and Habibidoost, M. *Energy Conversion and Management*, 2013, 71, 12–20.

In this paper, design, simulation, and conversion of a normal motorcycle to a hybrid electric motorcycle (HEM) is described. At first, a simple model designed and simulated using ADVISOR2002. Then, the controller schematic and its optimized control strategy are described. A 125 cm^3 internal combustion engine (ICE) motorcycle is selected and converted into a HEM. A brushless DC (BLDC) motor assembled in the front wheel and a normal internal combustion engine in the rear wheel propel the motorcycle. The nominal powers are 6.6 and 500 W for the ICE and BLDC, respectively. The original motorcycle has a continuous variable transmission (CVT) that is the best choice for a HEM power transmission because it can operate in the automatic handling mode and has high efficiency. Moreover, by using the CVT, the ICE can be started while motorcycle is running. Finally, three operating modes of HEM, two implemented energy control strategies, and HEM engine control system by servomotors, and LCD display are explained.

13/03468 Equalization integrated online monitoring of health map and worthiness of replacement for battery pack of electric vehicles

Ugle, R. *et al. Journal of Power Sources*, 2013, 223, 293–305.

Ever increasing acceptance of electric vehicles relies on better operation and control of large battery packs. The individual modules in large battery packs cannot have identical characteristics and may degrade differently due to manufacturing variability and other factors. Degraded battery modules waste more power, affecting the performance and economy for the whole battery pack. Also, such impact varies with different trip patterns. It is beneficial if the performance gain can be evaluated online prior to replacing certain battery module regarding to actual driving. In this paper, the research objectives are two-fold. First, an on-line battery module degradation diagnostic scheme is proposed using the intrinsic signals of battery module equalization. Without need for additional sensors or offline tests, this scheme is cost-effective for constructing and updating the battery pack 'health map' in real time during the vehicle operation. Secondly, based on the derived battery health map, the worthiness of replacement for certain modules/cells is proposed to evaluate the performance of the battery pack for customer specified trip. Such evaluation index provides a quantitative measure for module replacement and battery pack swapping Simulation study is performed to validate the proposed ideas using an actual driving cycle recorded for a commuting trip.

13/03469 Experimental studies on the dual-fuel sequential combustion and emission simulation

Lu, X. *et al. Energy*, 2013, 51, 358–373.

This study theoretically proposes and experimentally demonstrates the simultaneous reductions of NO_x and soot using a novel combustion mode, dual-fuel sequential combustion (DFSC), on a single-cylinder engine. DFSC introduces a well-mixed, lean fuel/air mixture into the cylinder by injecting high-cetane number fuel (*n*-heptane was used in this study) at the intake port followed by the direct injection of a high-octane number fuel (ethanol, iso-propanol, 1-butanol and iso-octane were used in this study) near the top dead centre (TDC). Four fuel combinations (*n*-heptane/iso-octane, *n*-heptane/ethanol, *n*-heptane/iso-propanol, and *n*-heptane/1-butanol) were operated with the DFSC mode in this study, and the ignition mechanism and combustion processes of each fuel combination were investigated. Three types of burn modes of directly injected fuels were observed: active atmosphere-dominated ignition, active-thermal atmosphere-dominated ignition, and thermal atmosphere-dominated ignition. The ignition timings of the directly injected fuels were strongly dependent on the premixed *n*-heptane concentration and were slightly influenced by the charge cooling effects. In the present testing conditions, the *n*-heptane/ethanol DFSC showed almost smokeless and ultra-low NO_x emissions at the maximum indicated (mean effective pressure) IMEP of 0.76 MPa. To increase understanding of the formation mechanisms of the HC and CO emissions in this combustion mode, three-dimensional (computational fluid dynamics) CFD coupled with reduced chemical kinetic mechanisms was used to simulate the *n*-heptane/iso-octane DFSC mode. Preliminary results show that the HC emissions originate primarily from the core region of the spray jet, where the fuel injection tip was unable to fully oxidize and burn. The CO emissions produce primarily at the boundary layer of the cylinder wall, piston ring crevice region, and combustion chamber bowl.

13/03470 Graphene based all-solid-state supercapacitors with ionic liquid incorporated polyacrylonitrile electrolyte

Tamilarasan, P. and Ramaprabhu, S. *Energy*, 2013, 51, 374–381.

This study reports the fabrication of a mechanically stable, flexible graphene based all-solid-state supercapacitor with ionic liquid incorporated polyacrylonitrile (PAN/[BMIM][TFSI]) electrolyte for electric vehicles (EVs). The PAN/[BMIM][TFSI] electrolyte shows high ionic conductivity (2.42 mS/cm at 28 °C) with high thermal stability. Solid-like layered phase of ionic liquid is observed on the surface of pores of PAN membrane along with liquid phase which made it possible to hold 400 wt% of mobile phase. This phase formation is facilitated by the ionic interaction of C≡N moieties with the electrolyte ions. A supercapacitor device, comprised PAN/[BMIM][TFSI] electrolyte and graphene as electrode, is fabricated and the performance is demonstrated. Several parameters of the device, like, energy storage and discharge capacity, internal power dissipation, operating temperature, safe operation and mechanical stability, meet the requirements of future EVs. In addition, a good cyclic stability is observed even after 1000 cycles.

13/03471 Lithium ion battery pack power fade fault identification based on Shannon entropy in electric vehicles

Zheng, Y. *et al. Journal of Power Sources*, 2013, 223, 136–146.

Fault diagnosis for inconsistent cells in a battery pack is important for electric vehicle (EV) safety. Discovering the fault and identifying its cause on-site are extremely challenging. The literature has rarely explored such issues. This paper presents a battery pack system in a demonstrated EV with 96 cells in series and discovers the battery power fade fault during the demonstration. The preliminary analysis, after collecting data and preprocessing the typical data periods, shows that the internal or contact resistance increase causes the fault. To further identify the fault cause, the authors introduced an equivalent circuit model and identified the cell resistances using the total least squares algorithm. A diagnostic method is proposed, using the identified cell resistances from 3 months demonstration data. Calculating the Shannon entropy clearly identifies the cause of the power fade fault. Appropriate measures were taken to solve the fault, and the latent safety issue was eliminated. The proposed diagnostic method can be used on-site for EV diagnosis without laboratory testing methods.

13/03472 Numerical study of combustion and emission characteristics of dual-fuel engines using 3D-CFD models coupled with chemical kinetics

Maghbouli, A. *et al. Fuel*, 2013, 106, 98–105.

Dual-fuel combustion provides a relatively easy and inexpensive alternative to conventional diesel engine combustion by drastically reducing fuel consumption with comparable performance characteristics. Accurate simulation of the dual-fuel combustion requires utilization of a detailed chemistry combined with a flow simulation code. In this study, the combustion process within the diesel and diesel/gas dual-fuel engine is investigated by use of a coupled 3D-CFD/chemical kinetics framework. Here, methane and *n*-heptane are used as representatives of the natural gas and diesel fuels. The multi-dimensional KIVA-3V code, with modified combustion and heat transfer models, incorporates a chemical kinetics mechanism for *n*-heptane and methane oxidation chemistry. The source terms in energy and species conservation equations due to chemical reactions are calculated by integrating the CHEMKIN chemistry solver into the KIVA code. The model is applied to simulation of a medium duty dual-fuel converted diesel engine. A chemical kinetics mechanism which consists of 42 species and 57 reactions is used for prediction of *n*-heptane oxidation chemistry. Simulation of dual-fuel combustion is performed using the same mechanism with addition of a series of major methane oxidation pathways. The results show that Zheng and Yao's *n*-heptane mechanism which had been previously validated in their work, can model the diesel and dual-fuel combustion, where fuel-rich zones are present. The predictive model of this study is validated using available published experimental data. Results show that pressure and ignition delay predictions are in good agreement with experiments. Based on constant total mixture input energy in dual-fuel combustion, increasing pilot fuel amount leads to shorter ignition delay and peak pressure increment. It is found that concentrations of NO_x and CO emissions tend to increase at higher pilot fuel injection quantities.

13/03473 Total cost of ownership, payback, and consumer preference modeling of plug-in hybrid electric vehicles

Al-Alawi, B. M. and Bradley, T. H. *Applied Energy*, 2013, 103, 488–506.

Motor vehicles represent one of the widely owned assets in the USA. A vehicle's ownership cost includes fixed expenses to purchase and own the vehicle and variable costs to use and operate the vehicle. Policymakers, analysts and consumers are interested in understanding the total ownership costs of various vehicle types and technologies so as to understand their relative consumer preference and valuation. Plug-in hybrid electric vehicles (PHEVs) are an advanced technology vehicle that is presently in limited production, but whose relative cost of ownership is not well defined. A few studies have attempted to calculate the costs and benefits of PHEVs but none consider the cost and benefits of PHEVs at a level of detail comparable to what has been performed for other vehicle technologies. In order to understand the costs and benefits of PHEVs purchase and use, this study constructs a comprehensive ownership cost model. The model is then used to analyse different PHEV designs within four vehicle classes. This study then performs a sensitivity analysis to understand the sensitivity of total ownership cost and payback period to model parameters and the modelled components of ownership costs. Results show that a more comprehensive PHEV ownership cost model has a lower net cost of ownership than studies to date, resulting in a shorter payback period and higher consumer preference.

Transport battery development

13/03474 Characterization of N-butyl-N-methyl-pyrrolidinium bis(trifluoromethanesulfonyl)imide-based polymer electrolytes for high safety lithium batteries

Kim, J.-K. *et al. Journal of Power Sources*, 2013, 224, 93–98.

Poly(vinylidene difluoride-co-hexafluoropropylene) (PVdF-HFP) membrane was prepared by electrospinning. The membranes served as host matrices for the preparation of ionic liquid-based polymer electrolytes (ILPEs) by activation with non-volatile, highly thermally stable, and safe room temperature ionic liquid (RTIL) electrolytes; N-butyl-N-methyl-pyrrolidinium bis(trifluoromethanesulfonyl)imide (Py_{14}TFSI) complexed with 1 M lithium bis(trifluoromethanesulfonyl)-imide (LiTFSI). In this work, the first combination of electrospun PVdF-HFP fibre polymer host and pyrrolidinium-based ionic electrolyte was employed for highly stable lithium batteries. The ILPE exhibited low Li^+–TFSI coordination, low crystallinity, high thermal stability, high electrochemical stability, and high ionic conductivity with a maximum of $1.1 \times 10^{-4}\,S\,cm^{-1}$ at 0 °C. The ILPE exhibited good compatibility with a $LiFePO_4$ electrode on storage and good charge–discharge performance in Li/ILPE/$LiFePO_4$ cells at room temperature, delivering specific capacities of 143 and 115 $mA\,h\,g^{-1}$ at 0.1 and 1 C-rates. The ILPE also exhibited stable cycle properties and have therefore been demonstrated to be suitable for lithium battery applications.

13/03475 Direct synchronous-asynchronous conversion system for hybrid electrical vehicle applications. An energy-based modeling approach

Muñoz-Aguilar, R. S. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 264–279.

This paper presents a proposal for a series hybrid electric vehicle propulsion system. This new configuration is based on a wound-rotor synchronous generator (WRSM) and a doubly-fed induction machine (DFIM). The energy-based model of the whole system is obtained taking advantage of the capabilities of the port-based modelling techniques. From the *dq* port-controlled Hamiltonian description of the WRSM and DFIM, the Hamiltonian model of the proposed direct synchronous-asynchronous conversion system (DiSAC) is developed. Subsequently, the bond graph models of the DiSAC and associate systems are also provided. Numerical simulations are also presented in order to validate the proposed system.

13/03476 Energy efficiency for the multiport power converters architectures of series and parallel hybrid power source type used in plug-in/V2G fuel cell vehicles

Bizon, N. *Applied Energy*, 2013, 102, 726–734.

This paper presents a mathematical analysis of the energy efficiency for the multiport power converter (MPC) used in series and parallel hybrid power source (HPS) architectures type on the plug-in fuel cell vehicles (PFCVs). The aim of the analysis is to provide general conclusions for a wide range of PFCV operating regimes that are chosen for efficient use of the MPC architecture on each particular drive cycle. In relation with FC system of PFCV, the energy storage system (ESS) can operate in following regimes: (1) charge-sustaining (CS), (2) charge-depleting (CD), and (3) charge-increasing (CI). Considering the imposed window for the ESS state-of-charge (SOC), the MPC can be connected to renewable plug-in charging stations (PCSs) to exchange power with electric power (EP) system, when it is necessary for both. The energy management unit (EMU) that communicates with the EP system will establish the moments to match the PFCV power demand with supply availability of the EP grid, stabilizing it. The MPC energy efficiency of the PFCVs is studied when the ESS is charged (discharged) from (to) the home/PCS/EP system. The comparative results were shown for both PFCV architectures through the analytical calculation performed and the appropriate Matlab/Simulink® simulations presented.

13/03477 Experimental investigation of the lithium-ion battery impedance characteristic at various conditions and aging states and its influence on the application

Waag, W. *et al. Applied Energy*, 2013, 102, 885–897.

In recent years, lithium-ion batteries have often been proposed as part of various hybrid energy systems. Examples of such applications are hybrid vehicles, photovoltaic-battery or wind-battery systems and power distribution grids. One of the key functions of a battery is to be source of an additional power when the main power source in the system cannot cover the power demands. The power capability of the battery is described by its impedance characteristic. It depends significantly on the battery state-of-charge (SoC), the temperature, the current and the previous history. In this paper, these dependencies and their variations over the battery lifetime are investigated on a 40 Ah lithium-ion cell produced by Kokam (Type SLPB100216216H) with nickel manganese cobalt oxide (NMC) cathode material as an example. For this purpose, a full characterization of the battery impedance is performed in the new and aged states using electrochemical impedance spectroscopy (EIS) and the current-pulse technique. The results obtained for the new and aged states are compared. The results show, for example, that the SoC range, in which the battery operates with high efficiency, decreases due to significant aging. For the first time, the non-linearity (current dependency) of the battery resistance is investigated extensively. It varies slightly with the SoC and considerably with the temperature, and it also changes during the battery lifetime. Furthermore, the dependency of the lithium-ion battery impedance on the short-time previous history is shown for the first time for a new and aged cell. The influence of the measured dependencies of the battery impedance on potential applications is discussed.

13/03478 Flexible free-standing graphene–TiO_2 hybrid paper for use as lithium ion battery anode materials

Hu, T. *et al. Carbon*, 2013, 51, 322–326.

Flexible and binder-free graphene–TiO_2 paper was prepared by a simple route. A unique three-dimensional nano-structure was achieved with nano-sized TiO_2 intercalated between graphene layers as pillars, significantly increasing the Li-ion insertion/extraction rate. At a current rate of $2\,A\,g^{-1}$, the specific capacity can reach $122\,mA\,h\,g^{-1}$ after 100 charge/discharge cycles. More remarkably, the flexible graphene/TiO_2 hybrid paper shows an excellent stability when the rates decrease from $4\,A\,g^{-1}$ back to $200\,mA\,g^{-1}$ with the retained capacity of $175\,mA\,h\,g^{-1}$.

13/03479 Increasing the rate capability of batteries with electrolyte flow

Kim, S. U. and Monroe, C. W. *Applied Energy*, 2013, 103, 207–211.

A theoretical analysis is provided to describe the recently proposed ‘convection battery’, wherein electrolyte flow is driven through a battery cell to alter its efficiency and power. Concentrated-solution theory rationalizes the observation that imposition of electrolyte flow parallel to the current through a separator can reduce overpotential losses. Equations are provided that allow this overpotential reduction to be computed in terms of the flow rate, as well as physical properties of the electrolyte and separator. Model results are consistent with earlier experimental observations of alkaline convection batteries. Current-coaxial flows with relatively low rates are found to allow fine-tuned control over limiting currents. Driving electrolyte flow through traditional rechargeable battery cells could facilitate very high charge rates.

13/03480 Investigation of nickel–metal hydride battery sorting based on charging thermal behavior

Fang, K. *et al. Journal of Power Sources*, 2013, 224, 120–124.

In this study, the sorting of nickel–metal hydride batteries is investigated based on their charging thermal behaviour. A self-organization map (SOM) model affiliated to artificial neural network is constructed to conduct the sorting work. The sorting principle is described in detail to support the model. A batch of batteries is charged in various rates to collect training data closely related to battery thermal behaviour. It is indicated that the model can master the regulation of sorting well after training. As a result, the batteries are classified by the SOM model into three categories of high heat generation battery, middle heat generation battery, and low heat generation battery, which corresponds well with the training result. The model thus allows the batteries in the same category to be selected for the consistency in thermal behaviour as well as discharge performance.

13/03481 On the business value of ICT-controlled plug-in electric vehicle charging in California

Goebel, C. *Energy Policy*, 2013, 53, 1–10.

The increasing penetration of variable renewable energy, such as wind and solar, requires the deployment of large scale energy storage or dynamic demand side management. Leveraging the intrinsic energy storage potential of certain electric loads could be the key for an efficient transition to green power generation. Plug-in electric vehicles (PEVs) are about to be introduced on a large scale. This paper investigates the savings potential of electricity retailers resulting from the ability to control the charging behaviour of a fleet of PEVs using information and communication technology (ICT). This savings potential is important as it could jumpstart the development of advanced control infrastructures for dynamic demand side management. The paper makes three major contributions: first, it applies a novel car usage model based on data from the national household travel survey. Second, it develops and evaluates several charging scheduling algorithms with low computational requirements. Third, it identifies several key parameters influencing the relative and absolute savings potential of ICT-controlled PEV charging. The authors obtain a relative savings potential of up to 45%. The absolute yearly savings per PEV, however, are rather small, which could limit the economic incentives of electricity retailers to deploy the required infrastructure.

13/03482 Simple fabrication of a Fe_2O_3/carbon composite for use in a high-performance lithium ion battery

Li, Y. *et al. Carbon*, 2013, 52, 565–573.

A simple approach was developed for the fabrication of a Fe_2O_3/carbon composite by impregnating activated carbon with a ferric nitrate solution and calcinating it. The composite contains graphitic layers and 10 wt% Fe_2O_3 particles of 20–50 nm in diameter. The composite has a high specific surface area of $\sim 828\,m^2\,g^{-1}$ and when used as the anode in a lithium ion battery, it showed a reversible capacity of $623\,mA\,h\,g^{-1}$ for the first 100 cycles at $50\,mA\,g^{-1}$. A discharge capacity higher than $450\,mA\,h\,g^{-1}$ at $1000\,mA\,g^{-1}$ was recorded in rate performance testing. This highly improved reversible capacity and rate performance is attributed to the combination of (i) the formation of graphitic layers in the composite, which possibly improves the matrix electrical conductivity, (ii) the interconnected porous channels whose diameters ranges from the macropore to mesopore, which increases lithium-ion mobility, and (iii) the Fe_2O_3 nanoparticles that facilitate the transport of electrons and shorten the distance for Li^+ diffusion. This study provides a cost-effective, highly efficient means to fabricate materials which combine conducting carbon with nanoparticles of metal or metal oxide for the development of a high-performance lithium ion battery.

13/03483 Synthesis and electrochemical performance of reduced graphene oxide/maghemite composite anode for lithium ion batteries

Kim, I. T. *et al. Carbon*, 2013, 52, 56–64.

Reduced graphene oxide (rGO) tethered with maghemite ($\gamma\text{-Fe}_2\text{O}_3$) was synthesized using a novel modified sol–gel process, where sodium dodecylbenzenesulfonate was introduced into the suspension to prevent the undesirable formation of an iron oxide three-dimensional network. Thus, nearly monodispersed and homogeneously distributed $\gamma\text{-Fe}_2\text{O}_3$ magnetic nanoparticles could be obtained on surface of graphene sheets. The utilized thermal treatment process did not require a reducing agent for reduction of graphene oxide. The morphology and structure of the composites were investigated using various characterization techniques. As-prepared rGO/Fe_2O_3 composites were utilized as anodes for half lithium ion cells. The 40 wt%-rGO/Fe_2O_3 composite exhibited high reversible capacity of 690 mA h g^{-1} at current density of 500 mA g^{-1} and good stability for over 100 cycles, in contrast with that of the pure-Fe_2O_3 nanoparticles which demonstrated rapid degradation to 224 mA h g^{-1} after 50 cycles. Furthermore, the composite showed good rate capability of 280 mA h g–^{1} at 10 C (~10,000 mA g^{-1}). These characteristics could be mainly attributed to both the use of an effective binder, poly(acrylic acid) (PAA), and the specific hybrid structures that prevent agglomeration of nanoparticles and provide buffering spaces needed for volume changes of nanoparticles during insertion/extraction of Li ions.

13/03484 Ultrahigh capacitance of nanoporous metal enhanced conductive polymer pseudocapacitors

Hou, Y. *et al. Journal of Power Sources*, 2013, 225, 304–310.

A high energy density is critical for supercapacitors to supersede conventional batteries for the applications where both high power and high energy are demanded. Here the authors report nanoporous metal/conductive polymer hybrid electrodes fabricated by electrochemically plating conductive polypyrrole into nanoporous channels of a dealloyed nanoporous metal. The low electric resistance and open porosity of the nanoporous metal give rise to excellent conductivity of electrons and ions and hence dramatically improved electrochemical performances of the pseudocapacitive polypyrrole. Supercapacitors based on the hybrid electrodes show an ultrahigh energy density of ~100 Wh kg^{-1} in a three-electrode, comparable to NiMH batteries, as well as high power density of ~57 kW kg^{-1}. Cycling stability measurements demonstrate that the hybrid electrode can retain 85% of the maximum capacitance after 3000 cycles and the degeneration is mainly caused by the dissolution of polypyrrole during charge/discharge cycling.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

13/03485 A high efficient micro-proton exchange membrane fuel cell by integrating micro-nano synergical structures

Peng, H.-S. *et al. Journal of Power Sources*, 2013, 225, 277–285.

A silicon-based micro-proton exchange membrane fuel cell (μ-PEMFC) which carries out an outstanding cell performance and high efficient catalyst utilization ratio is proposed in this paper by the employment of three micro-nano synergical techniques. Firstly, a novel design incorporating multi-walled carbon nano-tubes on radial shaped micro-channel walls to form micro/nano reaction chambers which significantly enhance the reaction surface areas for the performance improvement. In the second, the dispensing of ionomer onto the three-phase zones in the reaction chambers is controlled by different rotation speed and the optimized distribution can therefore be achieved for the improvement of catalyst utilization. In the third, the cell interfacial strength is greatly enhanced by the employment of micro-interlocks for maintaining excellent interface between Nafion membrane and reaction chambers while minimizing the system size. A μ-PEMFC is successfully fabricated by integrating aforementioned synergical micro/nano structures altogether. The best cell efficiency is 26 mW cm^{-2} which corresponds to a catalyst utilization ratio of 38.2 W g$_{\text{-pt}}{}^{-1}$, and can be considered among the best performed micro-fuel cells.

13/03486 A model of the long-wave radiation heat transfer through a glazing

Wang, T.-P. *et al. Energy and Buildings*, 2013, 59, 50–61.

Considering convection heat transfer between inside and outside surfaces of the glazing and conduction heat transfer of glass sheet, this paper presents a mathematical model of the long-wave radiation heat transfer between inside room surfaces and outside environmental surface through a glazing. The effects of three main factors on the overall heat flux are evaluated. Three main factors are the glass transmittance of long-wave radiation, convection heat transfer coefficient of inside and outside glass surface, the difference between the inside room surface temperature and the indoor air temperature as well as the difference between the outside environmental surface temperature and the outdoor air temperature. If the long-wave radiation transmittance approaches to 0.1, the effects of the transparence radiation of glass or some polymer material on the overall heat flux are obvious and cannot be ignored. The effects of convection heat transfer coefficient of inside and outside glass surface on the overall heat flux are relatively weak. If the temperature difference between the surface and air temperature is less than 2 °C, the effects on the overall heat flux and the role of the transparence radiation are weak. But if the difference is large, the effects are obvious and significant.

13/03487 Combined impacts of climate and wall insulation on the energy benefit of an extra layer of glazing in the facade

Mingotti, N. *et al. Energy and Buildings*, 2013, 58, 237–249.

This study explores the impacts of climate and wall insulation on the energy demand of a room connected to single or double glazing exposed to solar radiation. The authors show that in cold climates with weak solar radiation double glazing reduces the requirement for mechanical heating of buildings with poor wall insulation and/or small occupancy, particularly when its inner layer is tinted. In these climates the energy benefit of multi-layered glazing connected to well-insulated buildings with large internal heat gain is smaller. However, in warmer climates with stronger solar flux, double glazing reduces the requirement for mechanical cooling of buildings with good wall insulation and relatively small ventilation, particularly when its outer layer is tinted or highly reflective. For buildings with poor wall insulation located in warm climates with strong solar radiation, the energy saving provided by the extra layer of glazing in the facade is small.

13/03488 Comparative study of energy-efficiency and conservation systems for ceramic metal-halide discharge lamps

Orzáez, M. J. H. and de Andrés Díaz, J. R. *Energy*, 2013, 52, 258–264.

Interest in energy savings in urban lighting is gaining traction and has become a priority for municipal administrations. Light-emitting diode (LED) technology appears to be the clear future lighting choice. However, this technology is still rapidly developing and has not been sufficiently tested. As an intermediate step, alternative proposals for energy-saving equipment for traditional discharge lamps are desirable so that the current technologies can coexist with the new LED counterparts for the short and medium term. This paper provides a comparative study between two efficiency and energy-saving systems for discharge lamps with metal-halide and ceramic technologies, i.e. a lighting flow dimmer-stabilizer and a double-level electronic ballast. The study demonstrated that ceramic metal-halide lamps are dimmable with both energy-saving technologies without affecting the service life and the light quality. However, a 30% failure rate was observed for the dimmable electronic ballasts (without causing lamp failure). The savings that can be obtained with electronic ballasts are double (40%) that of the lighting flow dimmer-stabilizer equipment (20%). It has been shown that the illumination levels are reduced by the power-reduction percentage, without causing variations in the uniformity of lighting on the roads. The lighting flow dimmer-stabilizer needs up to 40% lesser investment than needed with the dimmable electronic ballasts system. It has been demonstrated that the profitability of the lighting flow dimmer-stabilizer system is far better than the dimmable electronic ballast one. In the first case the cost-benefit index is above the unit, and the values obtained for the different number of operation hours are double than those obtained for electronic ballasts. Besides, the payback periods are approximately half the ones needed for the electronic ballasts. The financial profitability for lighting flow dimmer-stabilizer is above capital costs, while the profitability of electronic ballasts is questioned. Despite the high and contrasted energy-efficiency and considerable savings from the system with the dimmable electronic ballasts (in excess of 40%), this system faces four main problems: high initial investment, low financial profitability, long payback periods, and high rate of failure due to thermal sensitivity.

13/03489 Development of a simplified and dynamic method for double glazing façade with night insulation and validated by full-scale façade element

Liu, M. *et al. Energy and Buildings*, 2013, 58, 163–171.

The study aims to develop a simplified calculation method to simulate the performance of double glazing façade with night insulation. This paper describes the method to calculate the thermal properties (*U*-value) and comfort performance (internal surface temperature of glazing) of the double glazing facade with the night insulation. The calculation result of the internal glazing surface temperature has been validated with experimental data collected in a full-scale façade element test facility at Aalborg University in Denamrk. With the help of the simplified method, dynamic *U*-value of the facade with night insulation is calculated and compared with that of the facade without the night insulation. Based on standards EN 410 and EN 673, the method takes the thermal mass of glazing and the infiltration between the insulation layer and glazing into account. Furthermore it is capable of implementing whole year calculation at different time steps. Acceptable accuracy and simplicity inputs are also the advantages of the method, which make it a suitable tool to evaluate the performance of night insulation during the design stage of buildings. The result calculated by the method proves that the facade with the night insulation performs much better than that without the night insulation.

13/03490 Effect of calcination temperature on the activity of solid Ca/Al composite oxide-based alkaline catalyst for biodiesel production

Meng, Y.-L. *et al. Bioresource Technology*, 2013, 128, 305–309.

A solid Ca/Al composite oxide-based alkaline catalyst containing $Ca_{12}Al_{14}O_{33}$ and CaO was prepared by chemical synthesis and thermal activation from sodium aluminate solution and calcium hydroxide emulsion. The effect of calcination temperatures ranging from 120 to 1000 °C on activity of the catalyst was investigated. The catalyst calcined at 600 °C showed the highest activity with >94% yield of fatty acid methyl esters (i.e. biodiesel) when applied to the transesterification of rapeseed oil at a methanol to oil molar ratio of 15:1 at 65 °C for 3 h. Structure and properties of the catalyst were studied and the characterizations with XRD, TGA, FTIR, BET, and SEM demonstrated that the performance of the catalyst was closely related to its specific surface area and crystalline structure. In particular, the generation of crystalline $Ca_{12}Al_{14}O_{33}$ improved the catalytic activity due its synergistic effect with CaO.

13/03491 Environmental, economic and energy analysis of double glazing with a circulating water chamber in residential buildings

Gil-Lopez, T. and Gimenez-Molina, C. *Applied Energy*, 2013, 101, 572–581.

In general, the glazed façade area of a building is the part that produces the greatest energy losses and gains. The basic aim of this work is to achieve a more efficient heat control in closed spaces. To this end, an exhaustive study has been made of active glazing comprising two laminated glass panels with a circulating water chamber. Not only has the energy consumption been analysed but also the energy efficiency according to fuel type, the amount of CO_2 emitted into the atmosphere and the economic cost. The results of this study, from the points of view of economic feasibility and energy efficiency, show that the solution of double glazing with a circulating water chamber is a less polluting and more efficient option than the systems currently used. This solution is able to reduce the energy losses and gains that are produced through the glazed façade of a building by 18.26% for calorific and frigorific energy compared to the total consumption of the building. The layout of the proposed installation facilitates its integration into any type of residential building, either under construction or being renovated. Moreover, its zero visual impact means it can even be implemented in places with strict town-planning regulations.

13/03492 Fully coupled transient modeling of ceramic foam volumetric solar air receiver

Wu, Z. and Wang, Z. *Solar Energy*, 2013, 89, 122–133.

Ceramic foam is a promising material for the absorber of volumetric solar air receiver in concentrated solar thermal power (CSP) plant. The transient behaviours of volumetric solar air receiver are crucial to the receiver's controllability, and to some extent, the plant's safety. This study numerically analyses the transient behaviours of volumetric solar air receiver under various working conditions. A fully coupled transient model of the volumetric solar air receiver is developed in this paper. The pressure drop of the absorber, the interfacial heat transfer between the flowing fluid and solid, and the radiative heat transfer due to concentrated solar radiation absorption by ceramic foam and the radiation transport inside the media were included together in this transient model. In addition, the temperature fields of the fluid and solid phases were obtained by using the local thermal non-equilibrium model. A comparison of the computed results with experimental data shows that this coupled transient model can be used to predict the performance of volumetric solar air receiver. Based on this model, the transient behaviours of the solar air receiver under a sudden heat flux, a sudden loss of heat flux, and a step change of heat flux were studied. The results of this study are very helpful in designing and controlling volumetric solar air receivers.

13/03493 High power millimeter wave experiment of torus diamond window prototype for ITER EC H&CD system

Takahashi, K. *et al. Fusion Engineering and Design*, 2013, 88, (2), 85–93.

The design of the torus diamond window for the ITER electron cyclotron heating and current drive (EC H&CD) system has advanced considering a reliable and manufacturable structure. The diamond window prototype was fabricated based on the design and the high power experiment was carried out to verify the millimetre wave transmission capability. Transmission of 740 kW at 100 s was demonstrated and no significant temperature increase of the window structure and no damage on the diamond disk were obtained. The temperature saturation of the cooling water for the window was observed and loss tangent of 7.8×10^{-6}, which was the lowest value ever obtained at the Japanese Atomic Energy Agency, was evaluated. This result indicates that the diamond window design is feasible and promising the high power more than 1 MW transmission.

13/03494 Hygrothermal behaviour and relative humidity buffering of unfired and hydrated lime-stabilised clay composites in a Mediterranean climate

Liuzzi, S. *et al. Building and Environment*, 2013, 61, 82–92.

Three different basic mixtures were prepared, by mechanical compaction, with different types of clays: quarry fine, kaolinite, and bentonite. Two groups of mixtures were studied, the first group without lime and the second with the addition of 5% hydrated lime. A comparison between the measured hygrothermal performances of the mixtures and their microstructural composition was performed. Microstructural morphology and chemical composition was characterized using SEM with EDS, mineralogy using XRD, and porosity using gravimetrics/He pycnometry and N_2 physisorption with BET and BJH analysis. Hygrothermal functional properties were characterized as moisture-dependent thermal conductivity, moisture-dependent heat capacity, vapour sorption isotherms, and water vapour permeability. The hygrothermal behaviour of a TESTROOM in a Mediterranean climate was simulated using WUFI Plus v2.1. The model simulated was repeated for three different internal surface types; an earth-bentonite panel, unpainted gypsum plaster, and an acrylic stucco plaster. Results demonstrated that the earth-bentonite gave the best hygric performance in terms of humidity buffering and, when used in conjunction with an HVAC system, achieved a significant (30%) operational energy saving in terms of humidification/dehumidification.

13/03495 Impact of iron on nuclear glass alteration in geological repository conditions: a multiscale approach

Burger, E. *et al. Applied Geochemistry*, 2013, 31, 159–170.

Interactions between nuclear glass and Fe were investigated in a clayey environment to better understand the mechanisms and driving forces controlling the long-term behaviour of high-level waste glass in a geological repository. An integrated experiment involving a glass–iron–clay (GIC) stack was run at a laboratory scale in anoxic conditions for 2 years and the interfaces were characterized by a multiscale approach using scanning electron microscopy coupled with energy dispersive spectroscopy, transmission electron microscopy, Raman microspectroscopy and scanning transmission X-ray microscopy at the SLS synchrotron. The characterization of glass alteration patterns on cross sections revealed an increase in glass alteration with the Fe content and the proximity between the glass and Fe. The alteration layers are polyphase and stratified with an inner porous gel layer incorporating Fe and an outer layer composed of nanocrystalline Fe-silicates. Several mechanisms which could affect the glass alteration kinetics and the transport properties of the alteration layer are proposed to explain this pattern: (i) consumption of hydrolysed silica by precipitation of Fe-silicates; (ii) penetration of Fe within the gel porosity probably as precipitates such as Fe oxyhydroxide or Fe-silicates. These new data may imply some consequences when considering the long-term behaviour of glass in geological disposal conditions.

13/03496 Improvement in stability of carbon support for platinum catalyst by applying silicon carbide coating

Suzuki, S. *et al. Journal of Power Sources*, 2013, 223, 79–85.

Silicon-carbide-coated carbon blacks (SiC/C) were investigated as support materials of platinum (Pt) nanoparticles to improve their stability. The support materials were synthesized by pyrolysing the mixture of polycarbosilane and carbon blacks. An elemental mapping image of the support material showed that the carbon black was coated with a layer of silicon carbide less than 10 nm thick. Both the electric resistance and surface area of the support materials were of the same order as the carbon black only. The platinum nanoparticles were deposited on the support materials by electroless plating. The oxygen reduction activity of the catalysts was measured electrochemically using a rotating disk electrode. The measurement showed that the specific activity of the catalyst increased when silicon carbide was added. The catalyst stability was evaluated using thermogravimetric (TG) analysis in air from room temperature to 1273 K and potential-cycling test between 1.0 and 1.5 V. These results revealed that the catalyst stability of Pt/SiC/C was higher than that of Pt/C. This high stability of Pt/SiC/C is attributed to the protective effect of SiC against carbon corrosion that is enhanced by the platinum nanoparticles.

13/03497 Liquid-filled solar glazing design for buoyant water-flow

Chow, T.-T. and Li, C. *Building and Environment*, 2013, 60, 45–55.

A water-flow window was constructed at the front wall of an environmentally controlled test cell to monitor its performance under full-scale real-building-like condition. The window was consisted of three layers, including one layer of clear glazing at the outside, one layer of insulated glazing unit at the inside, and one layer of water flowing in between. A heat exchanger was provided at the top of the window, and connected to the glazing cavity through connecting pipes and distribution headers. Through this, a cold feed water circuit removed the absorbed heat away from the buoyant water circulation in the window circuit. The heat removal allowed a reduction of energy consumption in air-conditioning and services hot water systems. Year round energy performance was then predicted by numerical models, which were successfully validated by the experimental data. A comparative study was also carried out with the use of different glazing types. The economical payback periods of the different glazing combinations are found less than 5 years under the Hong Kong subtropical climate. Amongst these, the energy performance of water-flow window with double absorptive glazing appears to be most promising.

13/03498 Pyrochlore based glass-ceramics for the immobilization of actinide-rich nuclear wastes: from concept to reality

Zhang, Y. *et al. Journal of Nuclear Materials*, 2013, 432, (1–3), 545–547.

Pyrochlore based glass-ceramics have been developed, from concept to reality, for the immobilization of actinide-rich nuclear wastes. Compared with zirconolite based glass-ceramics, they are less sensitive to the processing redox conditions and can double actinide waste loadings thus decreasing volumes of the consolidated waste forms, and subsequently reducing the interim storage and disposal costs. More importantly, they provide an alternative flexible system to tackle radioactive wastes arising from the advanced nuclear reactors.

13/03499 Regenerable MgO-based sorbent for high temperature CO_2 removal from syngas: 2. Two-zone variable diffusivity shrinking core model with expanding product layer

Abbasi, E. *et al. Fuel*, 2013, 105, 128–134.

The variable diffusivity model was extended to include physically expanding product layer and two reacting zones, consisting of a high-reactivity outer shell and a low-reactivity inner core, to describe the gas/solid carbonation reaction involving carbon dioxide and a potassium-promoted half-calcined dolomite sorbent. The model provides an excellent fit to the TGA experimental data on sorbent carbonation at various operating conditions. The parameters in the model which include an initial product layer diffusivity and diffusivity decay rate can correctly capture the trends on the effects of operating conditions on the physical properties of the sorbent observed in the experiments.

13/03500 Regional performance targets for transparent near-infrared switching electrochromic window glazings

DeForest, N. *et al. Building and Environment*, 2013, 61, 160–168.

With building heating and cooling accounting for nearly 14% of the national energy consumption, emerging technologies that improve building envelope performance have significant potential to reduce building energy consumption. Actual savings from these technologies will depend heavily upon their performance in diverse climate and operational conditions. In many cases, early-stage research can benefit from detailed investigation in order to develop performance thresholds and identify target markets. One example, a dynamic, highly transparent, near-infrared switching electrochromic (NEC) window glazing, is the focus of this investigation. Like conventional electrochromics, the NEC glazing can dynamically tune its optical properties with a small applied voltage. Consequently, the glazing can block or transmit solar heat to reduce cooling or heating loads, respectively. Unlike conventional electrochromics, NEC glazings remain transparent to visible light, causing no adverse effect to daylighting or building aesthetics. This study utilizes the software COMFEN to simulate a broad range of NEC performance levels, for commercial and residential buildings in 16 climate-representative reference cities. These simulations are the basis for identifying performance levels necessary to compete with existing static technologies. These results indicate that energy savings are strongly influenced by blocking-state performance. Additionally, residential applications have lower performance requirements due to their characteristic internal heat gains. Finally, the most dynamic NEC performance level is simulated in competition with high performing static alternatives. Here heating and cooling energy savings range from 5 to 11 kWh/m^{2}yr for commercial and 8–15 kWh/m^{2}yr for residential, in many regions on the order of 10%.

13/03501 The chemical durability of glass and graphite–glass composite doped with cesium oxide

Hamodi, N. H. *et al. Journal of Nuclear Materials*, 2013, 432, (1–3), 529–538.

The role of temperature in determining the chemical stability of a waste form, as well as its leach rate, is very complex. This is because the dissolution kinetics is dependent both on temperature and possibility of different rate-controlling mechanisms that appear at different temperature regions. The chemical durability of alumina-borosilicate glass (ABG) and glass–graphite composite (GGC), bearing tristructural isotropic (TRISO) fuel particles impregnated with caesium oxide, were compared using a static leach test. The purpose of this study is to examine the chemical durability of glass–graphite composite to encapsulate coated fuel particles, and as a possible alternative for recycling of irradiated graphite. The test was based on the ASTM C1220–98 methodology, where the leaching condition was set at a temperature varying from 298 to 363 K for 28 days. The release of caesium from ABG was in the permissible limit and followed the Arrhenius's law of a surface controlled reaction; its activation energy (E_a) was 65.6 ± 0.5 kJ/mol. Similar values of Ea were obtained for boron (64.3 ± 0.5) and silicon (69.6 ± 0.5 kJ/mol) as the main glass network formers. In contrast, the dissolution mechanism of caesium from GGC was a rapid release, with increasing temperature, and the activation energy of Cs (91.0 ± 5 kJ/mol) did not follow any model related to carbon kinetic dissolution in water. Microstructure analysis confirmed the formation of Crystobalite SiO_2 as a gel layer and Cs^{+1} valence state on the ABG surface.

13/03502 Thermal regeneration of the metal organic frameworks used in the adsorption of refractory organosulfur compounds from liquid fuels

Blanco-Brieva, G. *et al. Fuel*, 2013, 105, 459–465.

The metal organic framework (MOF) C300 system was used as a sorbent of benzothiophene (BT), dibenzothiophene (DBT) and 4,6-dimethyldibenzothiophene (DMDBT) from simulated diesel fuel at constant temperature (304 K) and initial sulfur concentration (1724 ppm). Once thermodynamic equilibrium was reached, thermal regeneration under inert flow within the temperature range 373–473 K was attempted and a second adsorption isotherm was recorded under exactly the same experimental conditions as the previous one. Regeneration at 473 K for all studied organosulfur compounds was only partial as shown by the lower level of adsorption regarding the fresh C300 sorbent. The recovered adsorption capacity was found to be a function of the boiling point of the three adsorbates, which means that the protocol employed to desorb the organosulfur compound (473 K, inert flow) allows only a fraction of the adsorbed phase to be desorbed, smaller for the S-containing molecules with a higher boiling point compound. In addition, it has been observed that the adsorption capacity recovered after the first cycle is maintained for further regeneration cycles. Adsorption of the sulfur compound is very strong, as shown by the slight drop in crystallinity and by the observation of a certain fraction of oxidized species (S(VI) moieties), as confirmed by the photoelectron spectra of the regenerated sorbent.

13/03503 Window spacers and edge seals in insulating glass units: a state-of-the-art review and future perspectives

Van Den Bergh, S. *et al. Energy and Buildings*, 2013, 58, 263–280.

Insulating glass (IG) units typically consist of multiple glass panes that are sealed and held together structurally along their perimeters. This report describes a study of edge seals in IG units. Several requirements must be taken into account when designing edge seals, including structural functionality, moisture and vapour transmission, life expectancy, and thermal performance. From this review of the literature on the state of the art in fenestration edge seals, it is clear that edge seal thermal performance has a significant effect on the *U*-value of a fenestration product and that, for best thermal performance, windows should use the best available spacers. Different strategies for defining thermal conductivity were discussed (i.e. the linear conductivity (k_{lin}), effective conductivity (k_{eff}), and equivalent conductivity (λ_{eq})). Each method has strengths and weaknesses inherent to their calculation procedures. Both k_{eff} and λ_{eq} are used for characterizing the thermal performance of the edge seal systems investigated in the market review. The market review categorized existing spacer systems according to their design and geometry in relation to their thermal performance. Although the relative merits of the different designs were not investigated, it is clear that non-metal spacers are the most promising future approach for window spacer designs. Among non-metal spacer materials, foams exhibit overall good thermal performance, generally somewhat better than that of thermoplastic spacers (TPSs). One composite spacer has good thermal performance compared to some foam and TPSs. Optimization of the thermal performance of individual spacers is necessary. Further research should be undertaken to improve insulating edge seal systems as well as to develop and investigate alternative materials and design possibilities. Improvement in edge seal thermal performance can be achieved by reducing the heat transfer width of the edge seal, reducing its thermal conductivity, and increasing its thickness (i.e. increasing the path length for heat loss). Decreasing the width of spacer bar and secondary sealant reduces the size of the thermal bridge at the edge of glass, thus increasing thermal performance. Spacer bars widths as small as 4.8 mm are currently available. Solutions to reduce the secondary sealant width are searched, but structural strength and durability must be retained. Composites provide for an interesting research field to reduce the edge seals thermal conductivity and the overall edge seal width. New composite designs could be explored that combine highly insulating materials such as polyurethane foam, aerogels, and vacuum material with other materials to create a component that meets all requirements. Corrugated edge seal designs are a potential area of research to increase the path length for heat transfer through the spacer bar. This idea could be adapted to accommodate triple-pane IG units, with a single spacer.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

13/03504 A GIS (geographical information system)-based spatial data mining approach for optimal location and capacity planning of distributed biomass power generation facilities: a case study of Tumkur district, India

Kaundinya, D. P. *et al. Energy*, 2013, 52, 77–88.

This paper primarily intends to develop a geographical information system (GIS)-based data mining approach for optimally selecting the locations and determining installed capacities for setting up distributed biomass power generation systems in the context of decentralized energy planning for rural regions. The optimal locations within a cluster of villages are obtained by matching the installed capacity needed with the demand for power, minimizing the cost of transportation of biomass from dispersed sources to power generation system, and cost of distribution of electricity from the power generation system to demand centres or villages. The methodology was validated by using it for developing an optimal plan for implementing distributed biomass-based power systems for meeting the rural electricity needs of Tumkur district in India consisting of 2700 villages. The approach uses a *k*-medoid clustering algorithm to divide the total region into clusters of villages and locate biomass power generation systems at the medoids. The optimal value of *k* is determined iteratively by running the algorithm for the entire search space for different values of *k* along with demand–supply matching constraints. The optimal value of the *k* is chosen such that it minimizes the total cost of system installation, costs of transportation of biomass, and transmission and distribution. A smaller region, consisting of 293 villages was selected to study the sensitivity of the results to varying demand and supply parameters. The results of clustering are represented on a GIS map for the region.

13/03505 An industrial level system with nonisothermal simultaneous solid state saccharification, fermentation and separation for ethanol production

Chen, H. and Li, G. *Biochemical Engineering Journal*, 2013, 74, 121–126.

To alleviate the problems of low substrate loading, non-isothermal, end-product inhibition of ethanol during the simultaneous saccharification and fermentation, a non-isothermal simultaneous solid state saccharification, fermentation, and separation (NSSSFS) process was investigated; one novel pilot-scale non-isothermal simultaneous solid-state enzymatic saccharification and fermentation coupled with CO_2 gas stripping loop system was invented and tested. The optimal pretreatment condition of steam-explosion was 1.5 MPa for 5 min in industrial level. In the NSSSFS, enzymatic saccharification and fermentation proceeded at around 50 and 37 °C, respectively, and were coupled together by the hydrolysate loop; glucose from enzymatic saccharification was timely consumed by yeast, and the formed ethanol was separated online by CO_2 gas stripping coupled with adsorption of activated carbon; the solids substrate loading reached 25%; ethanol yields from 18.96% to 30.29% were obtained in fermentation depending on the materials tested. Based on the pilot level of 300 L fermenter, a novel industrial-level of 110 m^3 solid state enzymatic saccharification, fermentation and ethanol separation plant had been successfully established and operated. The NSSSFS was a novel and feasible engineering solution to the inherent problems of simultaneous saccharification and fermentation, which would be used in large scale and in industrial production of ethanol.

13/03506 An overview of the composition and application of biomass ash. Part 1. Phase–mineral and chemical composition and classification

Vassilev, S. V. *et al. Fuel*, 2013, 105, 40–76.

An extended overview of the phase–mineral and chemical composition and classification of biomass ash (BA) was conducted. Some general considerations related to the composition of BA and particularly problems associated with this issue were discussed initially. Then, reference peer-reviewed data including phase–mineral composition and properties of BAs plus own investigations were used to describe and organize the BA system. It was found that BA is a complex inorganic–organic mixture with polycomponent, heterogeneous and variable composition. The phase–mineral composition of BA includes: (1) mostly inorganic matter composed of non-crystalline (amorphous) and crystalline to semi-crystalline (mineral) constituents; (2) subordinately organic matter consisting of char and organic minerals; and (3) some fluid matter comprising moisture and gas and gas–liquid inclusions associated with both inorganic and organic matter. Approximately 229 forming, major, minor or accessory phases or minerals were identified in BA. These species have primary, secondary or tertiary origin in the combustion residue and they are generated from natural (authigenic and detrital) and technogenic phases or minerals originally present in biomass. Common topics related to BA such as: terminology clarification; chemical composition; contents and concentration trends; correlations and associations; formation and behaviour; fusion temperatures; and leaching; were discussed and compared to coal ash. A general characterization of the phase–mineral composition and description of the occurrence and origin for common constituents in BA, namely: (1) silicates; (2) oxides and hydroxides; (3) sulfates (plus sulfides, sulfosalts, sulfites and thiosulfates); (4) phosphates; (5) carbonates (plus bicarbonates); (6) chlorides (plus chlorites and chlorates); (7) nitrates; (8) glass; (9) other inorganic phases; (10) organic phases; and (11) organic minerals; were also conducted and compared to coal ash. Finally, certain major associations related to the occurrence, content and origin of elements and phases were identified in the BA system and they include: (1) Si–Al–Fe–Na–Ti (mostly glass, silicates and oxyhydroxides); (2) Ca–Mg–Mn (commonly carbonates, oxyhydroxides, glass, silicates and some phosphates and sulfates); and (3) K–P–S–Cl (normally phosphates, sulfates, chlorides, glass and some silicates and carbonates). It was found that these systematic associations in BA have a key importance in both fundamental and applied aspects, namely their potential application for classification and indicator purposes connected with innovative and sustainable processing of BA. The potential utilization, technological and environmental advantages and challenges related to BA using the above classification approach are described in Part 2 of this work.

13/03507 An overview of the composition and application of biomass ash: Part 2. Potential utilisation, technological and ecological advantages and challenges

Vassilev, S. V. *et al. Fuel*, 2013, 105, 19–39.

An extended overview of the complex phase-mineral and chemical composition and properties of biomass ash (BA) was conducted in Part 1 of this work. Then, the identified systematic associations, namely (1) Si–Al–Fe–Na–Ti (mostly glass, silicates and oxyhydroxides); (2) Ca–Mg–Mn (commonly carbonates, oxyhydroxides, glass, silicates and some phosphates and sulfates); and (3) K–P–S–Cl (normally phosphates, sulfates, chlorides, glass and some silicates and carbonates); connected with the occurrence, content and origin of elements and phases in the BA system were used for classification of BAs into four types and six sub-types in Part 1. The potential application of BA using the above classification approach is described in Part 2. It is demonstrated that such new BA classification has not only fundamental importance, but also has potential applications in prediction of properties and utilization connected with the innovative and sustainable utilization of BAs specified in different types and sub-types. The potential advantages and challenges related to utilization of BA are described. Different aspects connected with BAs such as: (1) bulk utilization (for soil amendment and fertilization; production of construction materials, adsorbents, ceramics and other materials; plus synthesis of minerals); (2) recovery of valuable components and their utilization (char, water-soluble, cenosphere–plerosphere, magnetic and heavy fractions; and elements); and (3) multicomponent utilization; are described based on the reference investigations, present data and above classification. Subsequently, additional issues related to BAs, namely: (1) technological advantages and challenges (slagging, fouling and corrosion; low ash-fusion temperatures; erosion and abrasion; co-combustion and co-gasification; prediction of phase composition; and others); and (2) some environmental risks and health concerns (air, water, soil and plant contamination; acidity, alkalinity and leaching; volatilization, retention, capture and immobilization of hazardous elements and compounds; ash inhalation and disposal); during biomass and BA processing are also discussed. Finally, it is emphasized that the definitive utilization, technological and environmental advantages and challenges related to BAs associate preferentially with specific BA types and sub-types and they could be predictable to some extent by using the above combined chemical and phase-mineral classification approaches.

13/03508 Anaerobic methane production from five common grassland species at sequential stages of maturity

McEniry, J. and O'Kiely, P. *Bioresource Technology*, 2013, 127, 143–150.

Since grass will likely be a dominant feedstock for on-farm anaerobic digestion in north-west Europe, changes in the chemical composition of five common grass species with advancing harvest date in the primary growth were investigated and related to specific CH_4 yields. The increase in fibre components with advancing harvest date had a negative impact on the specific CH_4 yield (253 and 225 Nl CH_4 kg^{-1} VS for 12 May and 7 July harvests, respectively), and this impact was similar across the five grass species. At common growth stages, only small differences in herbage digestibility was observed between the grass species and this was reflected in similar specific CH_4 yields; however, the 26% lower area-specific CH_4 yield of the cocksfoot variety (*Dactylis glomerata* L. var. Pizza) would make it the most expensive of the five grass species to produce and the least suitable for anaerobic digestion.

13/03509 Best available carbon sources to enhance the via-nitrite biological nutrients removal from supernatants of anaerobic co-digestion

Frison, N. *et al. Chemical Engineering Journal*, 2013, 215–216, 15–22.

The best available external carbon source to enhance the short-cut nitrification–denitrification (SCND) and denitrifying phosphorus removal via nitrite (DPRN) was investigated using a demonstration sequencing batch reactor (SBR) to treat anaerobic supernatant. The SBR was inoculated with conventional activated sludge and fed with liquid effluent from anaerobic co-digestion of waste activated sludge and organic fraction of municipal solid waste. After the 20-day start-up, a stable and reliable via-nitrite pathway was achieved. Then, five best available carbon sources (acetic acid, glycerol, organic fraction of the municipal solid waste (OFMSW) fresh drainage liquid, OFMSW fermentation liquid, cattle manure and maize silage (CM&MS) fermentation liquid) were investigated. Glycerol did not cause major enhancement on nutrients removal. On the other hand, the authors found specific denitritation rates in the range 0.51–1.16 $kgNO_2$–N $kgVSS^{-1}$ day^{-1} for OFMSW and CM&MS related carbon sources. Specific consumptions were 2.1–2.3 kgCOD $kgNO_2\text{–}N^{-1}{}_{rem}$ for acetic acid and glycerol respectively, while OFMSW and CM&MS involved higher ratios 2.7–3.1 kgCOD $kgNO_2\text{–}N^{-1}{}_{rem}$. Thanks to the presence of short chain fatty acids (SCFAs), namely butyric and propionic acids, the fermentation liquids contemporary enhanced the DPRN up to 0.81 $kgPO'_4\text{–}P_{uptaken}$ $kgNO_2\text{–}N^{-1}{}_{removed}$. Thanks to the use of biowaste material, the cost of the external carbon source can be lower than €0.1 $kgCOD^{-1}$ when OFMSW is fermented. Therefore, the total specific cost for nitrogen removal may decrease of 22% when the OFMSW fermentation liquid is used instead of methanol.

13/03510 Bio-oil production through pyrolysis of blue-green algae blooms (BGAB): product distribution and bio-oil characterization

Hu, Z. *et al. Energy*, 2013, 52, 119–125.

Pyrolysis experiments of blue–green algae blooms (BGAB) were carried out in a fixed-bed reactor to determine the effects of pyrolysis temperature, particle size and sweep gas flow rate on pyrolysis product yields and bio-oil properties. The pyrolysis temperature, particle size and sweep gas flow rate were varied in the ranges of 300–700 °C, below 0.25–2.5 mm and 50–400 mL min^{-1}, respectively. The maximum oil yield of 54.97% was obtained at a pyrolysis temperature of 500 °C, particle size below 0.25 mm and sweep gas flow rate of 100 mL min^{-1}. The elemental analysis and calorific value of the oil were determined, and the chemical composition of the oil was investigated using gas chromatography–mass spectroscopy technique. The analysis of bio-oil composition showed that bio-oil from BGAB could be a potential source of renewable fuel with a heating value of 31.9 MJ kg^{-1}.

13/03511 Biodiesel degradation rate after refueling

Strömberg, N. *et al. Fuel*, 2013, 105, 301–305.

The overall objective of this study was to firmly investigate if the refuelling frequency influences the degradation rate of biodiesel and find out if primary and secondary oxidation products can act as initiators for biodiesel degradation in absence of metals. Duplicate samples of B7 reference fuel Euro VI and B100 methyl rape seed ester were studied during accelerated aging in an open to dry atmosphere system at an elevated temperature (80 °C) during 14 days. Determinations of water, short chain fatty acids as well as structural changes using infrared spectroscopy were used as degradation measures during aging and complemented with total acid number and hydroperoxide concentration at the end of the experiment. The study clearly shows that there are no autocatalytic effects from left-over fuel after refuelling and thus, the primary and secondary products do not directly influence the degradation rate of the fuel and that the fuel quality are in fact improved after refuelling as the remaining degradation products are diluted.

13/03512 Biodiesel from microalgae: a critical evaluation from laboratory to large scale production

Rawat, I. *et al. Applied Energy*, 2013, 103, 444–467.

The economically significant production of carbon-neutral biodiesel from microalgae has been hailed as the ultimate alternative to depleting resources of petro-diesel due to its high cellular concentration of lipids, resources and economic sustainability and overall potential advantages over other sources of biofuels. Pertinent questions however need to be answered on the commercial viability of large-scale production of biodiesel from microalgae. Vital steps need to be critically analysed at each stage. Isolation of microalgae should be based on the question of whether marine or freshwater microalgae, cultures from collections or indigenous wild types are best suited for large-scale production. Furthermore, the determination of initial sampling points play a pivotal role in the determination of strain selection as well as strain viability. The screening process should identify, purify and select lipid-producing strains. Are natural strains or stressed strains higher in lipid productivity? The synergistic interactions that occur naturally between algae and other microorganisms cannot be ignored. A lot of literature is available on the downstream processing of microalgae but a few reports are available on the upstream processing of microalgae for biomass and lipid production for biodiesel production. This review presents an empirical and critical analysis on the potential of translating research findings from laboratory scale trials to full-scale application. The move from laboratory to large-scale microalgal cultivation requires careful planning. It is imperative to do extensive pre-pilot demonstration trials and formulate a suitable trajectory for possible data extrapolation for large-scale experimental designs. The pros and cons of the two widely used methods for growing microalgae by photobioreactors or open raceway ponds are discussed in detail. In addition, current methods for biomass harvesting and lipid extraction are critically evaluated. This would be novel approach to economic biodiesel production from microalgae in the near future. Globally, microalgae are largest biomass producers having higher neutral lipid content outcompeting terrestrial plants for biofuel production. However, the viscosities of microalgal oils are usually higher than that of petroleum diesel.

13/03513 Catalytic cracking of vegetable oils and vacuum gas oil

Doronin, V. P. *et al. Fuel*, 2013, 106, 757–765.

The effect of vegetable oil unsaturation on the distribution and composition of the products of oil conversion over an equilibrium cracking catalyst was studied. Co-conversion of vacuum gas oil and vegetable oils under catalytic cracking conditions make it possible to increase the yield of gasoline fraction by 10 wt%. A maximum promoting effect is attained by the addition of 5–10 wt% vegetable oil. Investigation of joint transformations of n-undecane, tetralin and sunflower oil on cracking revealed that an increase in the yield of gasoline fraction can be related to the occurrence of hydrogen transfer reactions and manifestation of the competitive sorption effect.

13/03514 Change in particle size distribution of Torrefied biomass during cold fluidization

Rousset, P. *et al. Energy*, 2013, 51, 71–77.

Torrefaction is a thermochemical process for upgrading biomass that is usually run at temperatures ranging from 200 to more than 300 °C in an oxygen-free atmosphere and at ambient pressure. It is a useful pre-treatment technology for biomass that significantly alters its physical and chemical composition, making it more efficient in pulverized systems. This paper investigates the grindability of eucalyptus chips torrefied at temperatures ranging from 210 °C to 270 °C for a 15 min residence time, compared to raw material before and after fluidization. The tests were carried out in a cold flow fluidization bed chamber with an internal diameter of 150 mm, with air as the fluidizing medium and a chamber height of up to 750 mm. Biomass grindability was assessed by evaluating the change in particle size distribution. The results showed that the degree of thermal degradation depended on the temperature and was also influenced by particle size. The mean particle size of ground torrefied biomass decreased with an increase in torrefaction temperature. Lastly, for larger particles, it was possible to correlate the size distribution with the severity of the heat treatment by a simple linear equation in the experimental conditions used here.

13/03515 Cogeneration of biodiesel and nontoxic rapeseed meal from rapeseed through in-situ alkaline transesterification

Qian, J. *et al. Bioresource Technology*, 2013, 128, 8–13.

In situ alkaline transesterification of rapeseed oil with methanol for the production of biodiesel and non-toxic rapeseed meal was carried out. Water removal from milled rapeseed by methanol washing was more effective than vacuum drying. The conversion rate of rapeseed oil into FAME was 92%, FAME mass was 8.81 g, glucosinolates content in remaining rapeseed meal was 0.12% by methanol washing, while by vacuum drying the values were 46%, 4.44 g, 0.58%, respectively. In the presence of 0.10 mol/L NaOH in methanol, with methanol/oil molar ratio of 180:1 and a 3 h reaction at 40 °C, a conversion rate of 98% was achieved, and the glucosinolates content was reduce to 0.07%, a value which below the GB/T 22514–2008 standard in China. Thus the rapeseed meal can be used as a source of protein in animal feed. The FAME prepared through *in situ* alkaline transesterification met the ASTM specifications for biodiesel.

13/03516 Comparison of energy efficiency and economics of process designs for biobutanol production from sugarcane molasses

van der Merwe, A. B. *et al. Fuel*, 2013, 105, 451–458.

Development of technologies for biobutanol production by fermentation has resulted in higher final butanol concentrations, less fermentation by-products and higher volumetric productivities during fermentation, together with less energy intensive separation and purification techniques. These new technology developments have the potential to provide a production process for butanol from sugarcane molasses that is economically viable in comparison to the petrochemical pathway for butanol production. This objective was investigated by developing process models to compare three different possible process designs for biobutanol production from sugarcane molasses. The first two process routes incorporate well established industrial technologies: process route 1 consisted of batch fermentation and steam stripping distillation, while in process route 2, some of the distillation columns were replaced with a liquid–liquid extraction column. Some of the best production strains in these process routes, which include *Clostridium acetobutylicum* PCSIR-10 and *Cl. beijerinckii* BA101, can produce total solvent concentrations up to 24 g/L. Process route 3 incorporated fed-batch fermentation and gas-stripping with CO_2, an unproven technology on industrial scale. Process modelling in ASPEN PLUS® and economic analyses in ASPEN Icarus® were performed to determine the economic feasibility of these biobutanol production process designs. Process route 3 proved to be the only profitable design in current economic conditions in South Africa. Improved fermentation strains currently available are not sufficient to attain a profitable process design without implementation of advanced processing techniques. Gas stripping is shown to be the single most effective process step of those evaluated in this study, which can be employed on an industrial scale to improve process economics of biobutanol production.

13/03517 Does bio-oil derived from logging residues in Finland meet the European Union greenhouse gas performance criteria?

Sorsa, R. and Soimakallio, S. *Energy Policy*, 2013, 53, 257–266.

The renewable energy directive (RED) of the European Union (EU) sets mandatory targets for increasing the use of renewable energy in EU member states by 2020. The RED introduces sustainability criteria for transportation biofuels and other bioliquids in order to ensure that their increasing production does not cause serious environmental and social problems. Bio-oil production through fast pyrolysis is one technology under development. The aim of this paper is to explore whether bio-oil derived from logging residues in Finland meets the greenhouse gas performance criteria set by the EU. The pyrolysis reactor is assumed to be integrated with a combined heat and power production plant (CHP). Special attention is paid to uncertainty analysis. An emission reduction target of 60% as compared to the reference fuel is exceeded if the pyrolysis reactor and the CHP plant are considered as separate units, and changes in soil carbon balances are ignored. On the contrary, the particular target is not met using a 20-year time frame for changes in soil carbon balances. The results depend in large measure on the selection of parameters set and the interpretation of the definitions provided in the RED to set the system boundary for the pyrolysis reactor and the CHP plant.

13/03518 Effect of maize silage addition on biomethane recovery from mesophilic co-digestion of chicken and cattle manure to suppress ammonia inhibition

Yangin-Gomec, C. and Ozturk, I. *Energy Conversion and Management*, 2013, 71, 92–100.

The aim of this study is to evaluate the biogas recovery potential if mesophilic (35 ± 2 °C) anaerobic co-digestion of two different types of manure sources (from chicken and cattle) is applied at a biogas plant. In order to evaluate the improvement in biogas production in the presence of the co-substrate, maize silage is digested together with the animal manure. Results indicated that daily biomethane and total energy (power + heat) productions improved about 1.2-fold when maize silage is co-digested with cattle and chicken wastes. The heat and power energy potentials from the produced biogas were determined using the conversion rates of a CHP unit. Significant energy recovery could be achieved for both cases; i.e. total methane productions were calculated as 5800 and 6580 m^3/day corresponding to total energy productions of some 45.05×10^3 and 51.06×10^3 kW h without and with maize silage addition, respectively. A heat analysis was also performed where the resulting biomethane productions were the basis of the heat requirements. Results indicated that the major part of the heating requirements consisted of slurry heating to the operating temperature (in this study 35 °C). When the overall heat requirements are compared to the heat potential from a combined heat and power unit, it is clear that the heat produced is sufficient for successful mesophilic co-digestion giving energy savings as well as the excess heat can be utilized elsewhere in the premises of the biogas plant. Hence, treatment plants including co-digestion of chicken and cattle manure with a suitable co-substrate are becoming net producers of renewable energy if appropriate energy recovery technology is provided. Although the improvement in biogas and energy savings demonstrated that co-digestion of these two different organic wastes is viable with maize silage as the co-substrate, the co-digester needs control due to possible inhibition by high free ammonia levels especially from the chicken livestock.

13/03519 Effects of photobioreactors design and operating conditions on *Stichococcus bacillaris* biomass and biodiesel production

Olivieri, G. *et al. Biochemical Engineering Journal*, 2013, 74, 8–14.

Indoor cultures of *Stichococcus bacillaris* were carried out to investigate the effect of pH, CO_2, and hydrodynamics on biomass and biodiesel productivity in a 0.6 L vertical bubble column (VBC) and a 1.7 L inclined bubble column (IBC) photobioreactor. The temperature and the irradiance level were set at 23 °C and 300 μE/(m^2 s), respectively. The pH of the liquid culture was in the range 3.0–8.5. The CO_2 concentration in the gas phase was increased up to 15%, typical of exhaust gas from power plants. The increased CO_2 concentration in the gas phase stimulated the microalgal growth. Tests carried out at different pH and spreading a 5% CO_2 gas stream showed that the biomass productivity was maximum at a pH of about 7.0. Acid and alkaline conditions can also be adopted with an approximate 25% decrease in biomass productivity. The comparison between a IBC and a VBC reactor operated under the same conditions pointed out that the performances of IBC were higher than those of VBC: $0.26\,g_{biomass}/(L\,d)$ and $0.032\,g_{FAME}/(L\,d)$ for IBC, and $0.124\,g_{biomass}/(L\,d)$ and $0.010\,g_{FAME}/(L\,d)$ for VBC. IBC was characterized by an intensive liquid circulation that promotes a continuous renewal of microalgal cells in the photic zone.

13/03520 Fast pyrolysis of microalgae remnants in a fluidized bed reactor for bio-oil and biochar production

Wang, K. *et al. Bioresource Technology*, 2013, 127, 494–499.

In this study, pyrolysis of microalgal remnants was investigated for recovery of energy and nutrients. *Chlorella vulgaris* biomass was first solvent-extracted for lipid recovery then the remnants were used as the feedstock for fast pyrolysis experiments using a fluidized bed reactor at 500 °C. Yields of bio-oil, biochar, and gas were 53, 31, and 10 wt%, respectively. Bio-oil from *C. vulgaris* remnants was a complex mixture of aromatics and straight-chain hydrocarbons, amides, amines, carboxylic acids, phenols, and other compounds with molecular weights ranging from 70 to 1200 Da. Structure and surface topography of the biochar were analysed. The high inorganic content (potassium, phosphorous, and nitrogen) of the biochar suggests it may be suitable to provide nutrients for crop production. The bio-oil and biochar represented 57% and 36% of the energy content of the microalgae remnant feedstock, respectively.

13/03521 Harvesting economics and strategies using centrifugation for cost effective separation of microalgae cells for biodiesel applications

Dassey, A. J. *et al. Bioresource Technology*, 2013, 128, 241–245.

Inefficient or energy-intensive microalgal harvesting strategies for biodiesel production have been a major setback in the microalgae industry. Harvesting by centrifugation is generally characterized by high capture efficiency (>90%) under low flow rates and high energy consumption. However, results from the present study demonstrated that by increasing the flow rates (>1 L/min), the lower capture efficiencies (<90%) can be offset by the larger volumes of culture water processed through the centrifuge, resulting in net lower energy consumption. Energy consumption was reduced by 82% when only 28.5% of the incoming algal biomass was harvested at a rate of 18 L/min by centrifugation. Harvesting algal species with a high lipid content and high culture density could see harvesting costs of $0.864/L oil using the low efficiency/high flow rate centrifugation strategy as opposed to \$4.52/L oil using numbers provided by the Department of Energy for centrifugation harvesting.

13/03522 Mapping energy crop cultivation and identifying motivational factors among Swedish farmers

Ostwald, M. *et al. Biomass and Bioenergy*, 2013, 50, 25–34.

Based on a meta-study, the paper describes the existing options, areal extents, and Swedish farmers' conditions for energy crop production promoted by the governments to mitigate and adapt to climate change. The drivers of and barriers to cultivating various energy crops are described in terms of a variety of motivational factors. The approach used peer-reviewed and grey literature using three Internet sources. Questions addressed include the energy crops available to Swedish farmers and how well established they are in terms of areal extent. What drivers of and barriers to growing energy crops do farmers perceive? How do various motivational factors for these drivers and barriers correspond to the adoption of certain energy crops? The results indicate that 13 energy-related crops are available, of which straw (a residue), oil crops, and wheat are the most extensively produced in terms of cultivated area. Results confirm earlier research findings that converting from annual to perennial crops and from traditional crops or production systems to new ones are important barriers. Economic motivations for changing production systems are strong, but factors such as values (e.g. aesthetic), knowledge (e.g. habits and knowledge of production methods), and legal conditions (e.g. cultivation licenses) are crucial for the change to energy crops. Finally, there are knowledge gaps in the literature as to why farmers decide to keep or change a production system. Since the Swedish government and the European Union intend to encourage farmers to expand their energy crop production, this knowledge of such motivational factors should be enhanced.

13/03523 Mathematical modelling of anaerobic digestion of biomass and waste: power and limitations

Lauwers, J. *et al. Progress in Energy and Combustion Science*, 2013, 39, (4), 383–402.

Anaerobic digestion is an excellent technique for the energetic valorization of various types of biomass including waste forms. Because of its complex nature, the optimization and further process development of this technology go hand in hand with the availability of mathematical models for both simulation and control purposes. Over the years, the variety of mathematical models developed has increased as have their complexity: starting from very simplified models that consider digestion as a fermentation process from sugars, to the advanced and extended models such as ADM1. The latter can be thought of as a conjunction of 'knowledge' on anaerobic digestion modelling. It comes in three versions and many adaptations have been made to address certain caveats or specific digestion situations. It is mainly used as a benchmark, either stand-alone or in a plant-wide model, which requires interfacing. Additionally, more parsimonious models are nevertheless used for control purposes. The proposed models use easy-to-measure variables and their simplicity makes a whole myriad of control actions possible, with or without state estimation. Although major interest is given to the development of mechanistically inspired models, they are not the only prodigy of modelling efforts. Black-box models, based either on statistical methods or heuristical information give elegant solutions to estimation problems, on the precondition that sufficient data is available. The models mentioned in this review are suited for the conditions mentioned in their respective references, but the approaches can be valuable for user-specific conditions, i.e. other data sets. It is believed that future developments will primarily focus on the biological aspect of modelling: mathematically relating the performance of a digestion to microbial diversity and activity.

13/03524 Methane production from cattle manure supplemented with crude glycerin from the biodiesel industry in CSTR and IBR

Castrillón, L. *et al. Bioresource Technology*, 2013, 127, 312–317.

The aim of the present research work was to optimize biogas production from cattle manure by adding crude glycerin from the biodiesel industry. For this purpose, 6% v/v crude glycerin (the optimum amount according to previous research) was added to ground manure and the mixture was sonicated to enhance biodegradability prior to anaerobic co-digestion at 55 °C. Two different reactors were used: continuously stirred (CSTR) and induced bed (IBR). The methanol and pure glycerin contents of the crude glycerin used in this study were 5.6% and 49.4% (w/w), respectively. The best results when operating in CSTR were obtained for an organic loading rate (OLR) of 5.4 kg COD/m^3 day, obtaining 53.2 m^3 biogas/t wet waste and 80.7% COD removal. When operating in IBR, the best results were obtained for an OLR of 6.44 kg COD/m^3 day, obtaining 89.6% COD removal and a biogas production of 56.5 m^3/t wet waste.

13/03525 Novel application of cotton stalk as a waste derived catalyst in the low temperature SCR-deNO$_x$ process

Singh, S. *et al. Fuel*, 2013, 105, 585–594.

The use of activated carbon derived from cotton stalk as a potential catalytic support material in the application of NO removal from coal combusted flue gas was experimentally investigated utilizing the SCR-deNO$_x$ process. Cotton stalk samples infused with phosphoric acid were chemically activated (CACS) and co-activated (CO-ACS) and impregnated with the metal configuration Mn/Ce (1:2 M ratio) representing 4 wt% relative to the support material. The CACS$_x$–Mn/Ce and CO-ACS$_x$–Mn/Ce catalysts provided NO conversion efficiencies ranging between ~10% and 68%. The addition of phosphoric acid significantly increased the BET surface area (m^2 g^{-1}) of the respective CACS$_x$–Mn/Ce and CO-ACS$_x$–Mn/Ce catalysts. However based on the experimental and analytical findings this study suggests that the NO conversions efficiencies of the CACS$_x$–Mn/Ce and CO-ACS$_x$–Mn/Ce catalysts are far more dependent on the weight percentage of the metal loading than the physical parameters such as the pore size, pore structure and surface area. The relatively lower NO conversion efficiencies may also be further due to the neutralization of the Lewis and Brönsted acid sites of the catalysts by the presence of any alkali metals within the cotton stalk. The cotton stalk derived catalytic support has shown a great potential for possible application within the SCR-deNO$_x$ process. It is further suggested that higher NO conversion efficiencies can be realized by an increase in the metal loadings of Mn/Ce for the CACS$_x$–Mn/Ce and CO-ACS$_x$–Mn/Ce catalysts.

13/03526 Performance evaluation of a direct-biogas solid oxide fuel cell-micro gas turbine (SOFC-MGT) hybrid combined heat and power (CHP) system

Wongchanapai, S. *et al. Journal of Power Sources*, 2013, 223, 9–17.

The combination of a direct-biogas solid oxide fuel cell (SOFC) with a micro gas turbine (MGT) system offers great potential as a green decentralized combined heat and power (CHP) system. To evaluate the potential use of biogas as the main source of energy for a direct-biogas SOFC-MGT hybrid CHP system, a sensitivity analysis was conducted under diverse operating conditions to investigate the influence of key operating parameters of the hybrid CHP system with the consideration of operational constraints. The key parameters in this study were SOFC reforming agent, SOFC fuel utilization factor (U_f), turbine inlet temperature (TIT), and compression ratio. The influence of variation in operating parameters on plant performance was evaluated for the overall system and SOFC efficiencies as well as the heat-to-power ratio (TER), the power ratio of MGT to SOFC (P_{MGT}/P_{SOFC}), and the size of the SOFC stack. As a reforming agent for direct-biogas SOFC, steam is more preferable than a traditional air–steam mixture in terms of material limitations and SOFC efficiencies; however, an air–steam mixture with a small amount of air boosts the useful heat output and electricity generated by an MGT without significantly affecting overall system efficiency. The increase in U_f improves the electrical power output produced by the SOFC stack, but also requires more fuel to be fed to the burner, resulting in an increase in useful heat energy. Increasing the compression ratio improves the system electrical efficiency but lowers useful heat generation; nevertheless, increasing TIT decreases the system electrical efficiency but improves the efficiency of the CHP system. To achieve the optimum operating conditions of the hybrid CHP system, the operating parameters should be determined based on the desired energy outcomes.

13/03527 Performance of a flat panel reactor in the continuous culture of microalgae in urban wastewater: prediction from a batch experiment

Ruiz, J. *et al. Bioresource Technology*, 2013, 127, 456–463.

A laboratory-scale flat panel photobioreactor was operated for the continuous growth of *Scenedesmus obliquus* and consequent removal of nutrients in wastewater. This study develops a simple model by which biomass values in continuous operation can be predicted from kinetic growth parameters obtained from a shorter batch experiment. Based on this study, biomass concentrations and productivities in continuous operation can be successfully predicted as a function of the specific hydraulic retention time (*HRT*) assumed. Considerable biomass production and nutrient uptake from wastewater were achieved in the experiment. Optimum operating conditions for the reactor depend on the particular objective: the maximization of biomass production and carbon dioxide biofixation involves a *HRT* of $2\,\mu^{-1}$ (specific growth rate), whereas efficient nutrient removal involves a *HRT* as close as possible to μ^{-1} (as long as discharges comply fully with the parameters set); alternatively biomass intended for biodiesel or biogas production would involve a $HRT > 2\,\mu^{-1}$.

13/03528 Preparation and characterization of Cs/Al/Fe$_3$O$_4$ nanocatalysts for biodiesel production

Feyzi, M. *et al. Energy Conversion and Management*, 2013, 71, 62–68.

Cs/Al/Fe$_3$O$_4$ nanocatalysts were prepared via novel synthesis method. This research investigated the effects of different Cs/Al and Cs/Fe molar ratio and calcination conditions on the catalytic performance of Cs/Al/Fe$_3$O$_4$ catalysts for biodiesel fatty acids methyl ester production. It was found that the catalyst with Cs/Al = 2.5/1 and Cs/Fe = 4/1 molar ratio was an optimal catalyst for biodiesel production. The activity of optimal catalyst was studied in different operational conditions. The results showed that the best operational conditions were the oil/CH$_3$OH = 1/14 at 58 °C with mechanical stirring for 120 min. Furthermore, the optimal catalyst showed high catalytic activity for biodiesel production and the biodiesel yield reached 94.8% under the optimal conditions. Characterization of catalysts was carried out by using scanning electron microscopy, X-ray diffraction, transmission electron microscopy and N$_2$ adsorption–desorption measurements methods.

13/03529 Process intensification for biodiesel production from *Jatropha curcas* L. seeds: supercritical reactive extraction process parameters study

Lim, S. and Lee, K. T *Applied Energy*, 2013, 103, 712–720.

In a bid to increase the cost competitiveness of biodiesel production against mineral diesel, process intensification has been studied for numerous biodiesel processing technologies. Subsequently, reactive extraction or *in situ* transesterification is actively being explored in which the solid oil-bearing seeds are used as the reactant directly with short-chain alcohol. This eliminates separate oil extraction process and combines both extraction and transesterification in a single unit. Supercritical reactive extraction takes one step further by substituting the role of catalyst with supercritical conditions to achieve higher yield and shorter processing time. In this work, supercritical reactive extraction with methanol was carried out in a high-pressure batch reactor to produce fatty acid methyl esters (FAMEs) from *Jatropha curcas* L. seeds. Material and process parameters including space loading, solvent to seed ratio, co-solvent (*n*-hexane) to seed ratio, reaction temperature, reaction time and mixing intensity were varied one at a time and optimized based on two responses i.e. extraction efficiency, M_{extract} and FAME yield, F_{y}. The optimum responses for supercritical reactive extraction obtained were 104.17% w/w and 99.67% w/w (relative to 100% lipid extraction with *n*-hexane) for M_{extract} and F_{y} respectively under the following conditions: 54.0 ml/g space loading, 5.0 ml/g methanol to seeds ratio, 300 °C, 9.5 MPa (Mega Pascal), 30 min reaction time and without *n*-hexane as co-solvent or any agitation source. This proved that supercritical reactive extraction is rather promising as another alternative for biodiesel production.

13/03530 Quantitative analysis of potential power production and environmental benefits of biomass integrated gasification combined cycles in the European Union

Escudero, M. *et al. Energy Policy*, 2013, 53, 63–75.

Biomass integrated gasification combined cycles (BioIGCC) are a promising technology, alternative to fossil fuels for power generation. Significant reduction of CO$_2$ emissions could be achieved, although important changes in the gas turbines and gasifiers design and further technological development would be necessary. The aim of this work is to study quantitatively the benefits of using BioIGCC plants instead of fossil fuel technologies, in terms of power supply and CO$_2$ emission avoidance, including the study of pre-combustion CO$_2$ capture. Different biomass substrates are analysed and compared and the required land use in each case and for different scenarios is also studied and quantified. The power generation and greenhouse gas emission avoidance potential of BioIGCC technology in Europe is also studied and the viability of this technology in different circumstances is discussed. In several cases BioIGCC plants are found to be viable from the point of view of availability of biomass resources and the cost of the produced kWh. In the whole EU-27 the potential hovers around 30 GW and a reduction of nearly 4% of the total EU emissions in 2009 in a conservative scenario, and up to 100 GW and 15% of emission reduction in a more optimistic one.

13/03531 Synthesis of biodiesel in subcritical water and methanol

Ju, Y.-H. *et al. Fuel*, 2013, 105, 266–271.

A novel method for biodiesel production without the need of conventional catalyst such as potassium hydroxide and sulfuric acid was proposed in this study. In the presence of water, biodiesel can be produced by reacting methanol with feedstock oil under subcritical condition. When refined soybean oil was used, high biodiesel conversion (96.4%) can be achieved in a reasonable short time (4 h). The conversion was 92.6% when soybean oil with a water content of 9 wt% was used. The possibility of using oils with high acid and water contents as feedstock was also investigated. Since no catalyst was employed, the process is simpler and more environmental friendly than traditional methods.

13/03532 Techno-economic analysis of biomass to transportation fuels and electricity via fast pyrolysis and hydroprocessing

Brown, T. R. *et al. Fuel*, 2013, 106, 463–469.

A previous Iowa State University (ISU) analysis published in 2010 investigated the technical and economic feasibility of the fast pyrolysis and hydroprocessing of biomass, and concluded that the pathway could produce cellulosic biofuels for a minimum fuel selling price (MFSP) of $2.11/gal. The 2010 ISU study was largely theoretical in that no commercial-scale fast pyrolysis facilities were being constructed at the time of publication. The present analysis expands upon the 2010 ISU study by performing an updated techno-economic analysis of the fast pyrolysis and hydroprocessing pathway. Recent advances in pathway technology and commercialization and new parameters suggested by the recent literature are accounted for. The MFSP for a 2000 MTPD facility employing fast pyrolysis and hydroprocessing to convert corn stover to gasoline and diesel fuel is calculated to quantify the economic feasibility of the pathway. The present analysis determines the MFSP of gasoline and diesel fuel produced via fast pyrolysis and hydroprocessing to be $2.57/gal. This result indicates that the pathway could be competitive with petroleum, although not as competitive as suggested by the 2010 ISU study. The present analysis also demonstrates the sensitivity of the result to process assumptions.

13/03533 Techno-economic assessment of micro-algae as feedstock for renewable bio-energy production

Jonker, J. G. G. and Faaij, A. P. C. *Applied Energy*, 2013, 102, 461–475.

This paper determines the energy consumption ratio and overall bio-energy production costs of micro-algae cultivation, harvesting and conversion to secondary energy carriers, thus helping to clarify future perspectives of micro-algae production for energy purposes. A limitation growth model is developed, which determines the productivity of micro-algae for different climate profiles. Total direct and indirect energy consumption ratios for the production of heat, fuels and electricity derived from micro-algae are calculated. Overall direct energy consumption ratio for raceway ponds is 0.06 for the optimal case, indirect energy consumption ratio for that case is 0.74. Direct energy consumption ratio in horizontal tubular systems is 0.32 for the optimal case, indirect energy consumption ratio for that case is 117. The implementation of different improvement options could reduce the indirect energy consumption ratio by 50% for both raceway ponds and horizontal tubular systems in the optimistic scenario. Prominent elements of the energy consumption ratios are carbon dioxide supply for raceway ponds and circulation power consumption for horizontal tubular systems. The lower end of fuel production cost calculated for raceway ponds is 136 €2010/GJ and 153 €2010/GJ for horizontal tubular systems (non-renewable gasoline and diesel is about 5–20 €/GJ). Considering possible improvement options overall bio-energy production costs could be reduced by one-fourth. Current results suggest that micro-algae cultivation is not suitable for dedicated bio-energy production in considered cultivation, harvesting and conversion options. Coproduction of bio-energy with high-value products are more viable, but is not considered in this research.

13/03534 Techno-economic evaluation of masonry type animal feed solar cooker in rural areas of an Indian state Rajasthan

Panwar, N. L. *et al. Energy Policy*, 2013, 52, 583–586.

Utilization of animal draft power in agricultural operation and milk production is highly dependent on the feed and fodder. Properly cooked feed is digestive in nature and enhance milk production. Solar energy is promising option for slow cooking. Keeping this in view a masonry animal feed solar cooker (AFSC) was developed. It helps in the number of ways to improve the living standard of rural farmers and also reduce the CO$_2$ emission by replacing conventional fossil fuel. The AFSC can replace the 100% biomass and save about 424.80 kg of CO$_2$ on annual basis and save about INR24 per day. Usually women prepare animal feed in rural areas, hence cooking with AFSC saves time and this time can be used to take care of her family or in agricultural operation. This paper presents fuel replacement and reduction of carbon dioxide on annual basis and economic evaluation of AFSC.

13/03535 The effect of microwave pretreatment on biogas production from agricultural straws

Sapci, Z. *et al. Bioresource Technology*, 2013, 128, 487–494.

Biogas production from microwave-pretreated agricultural residual straws that are used as feedstock was investigated in a laboratory batch study. Barley, spring wheat, winter wheat and oat straw were examined. To investigate the effect of changing the physicochemical structure of the straws on biogas production, the pretreatment processes were applied to two sample groups. The first group contained milled straw and the second group comprised milled wet straw that was prepared by the addition of deionized water. Both groups were subjected to microwave irradiation until oven temperatures of 200 or 300 °C were attained. Sixty-six identical batch anaerobic reactors were run under mesophilic conditions for 60 days. Preliminary test results showed that the microwave pretreatment of the different straws did not improve their anaerobic digestion. An increase in the treatment temperature led to lower biogas production levels. An inverse relationship between the thermal conversion yield and cumulative biogas production was observed.

13/03536 The progress and prospects of rural biogas production in China

Chen, L. *et al. Energy Policy*, 2012, 51, 58–63.

Biogas production is an important aspect of China's energy strategy. After decades of application and research, China biogas has achieved considerable accomplishments. This study presents the progress and prospect of biogas technologies and industry in China. Two biogas patterns exist in China, that is, household-scaled digester for scattered farmers and biogas plant for centralized biogas production. Household-scaled digester which is simple and practical has been widely used and fully developed. Biogas plants have being sprung up with different materials, process and biogas utilization technologies. By the end of 2010, 38.51 million household-scaled digesters, and 27,436 large- and medium-scaled biogas plants for agricultural wastes were built. The calculation result of biogas potential from agricultural wastes shows that those used raw materials account for only 1.90% of the total availability. Chinese government promulgated several laws and policies, and gave financial supports to promote the development of biogas. However, some problems such as inferior equipment technology, imperfect policy incentive hamper its wide application and promotion. With the rapid development of economy and the improvement of rural living condition, China biogas industry is expected to advance toward orientation of scalization, industrialization and commercialization.

13/03537 Thermal evaluation of structural concretes for construction of biodigesters

Ramírez, F. M. D. *et al. Energy and Buildings*, 2013, 58, 310–318.

The following study consists of the thermal evaluation of the enclosure of a reinforced concrete biodigester, through the theoretical analysis of the influence of each component of the materials in the whole mixture, depending on the distinct values of thermal conductivity of the concrete. To determine this variable in each specific case, a review of the theoretical models developed over the years by experts in the field has been made to find the most suitable model for the case under study. The effect on the thermal conductivity of the variation in type and proportion of the basic elements making up the concrete is studied: the aggregate, the cement, the water/cement ratio, the porosity and the humidity among others, with the aim of providing a tool for estimating the thermal conductivity of a concrete created with the desired proportions. This tool is designed in the form of a nomogram for each specific case, in which conventional concrete, concrete with recycled aggregate from construction and demolition waste and lightweight structural concrete are differentiated.

13/03538 Using geographic information systems to assess potential biofuel crop production on urban marginal lands

Niblick, B. *et al. Applied Energy*, 2013, 103, 234–242.

To meet rising energy demands in a sustainable manner, the US Renewable Fuel Standard 2 (RFS2) mandates the production of 3.78 billion litres (1 billion gallons) of biomass-based biodiesel per year by 2020. Urban marginal lands, herein defined as lots with poor agricultural potential and unfit for residential purposes, can be used to cultivate biodiesel feedstock, which can contribute toward the RFS2. GIS is particularly well suited to identify the amount and location of these urban marginal lands. Biofuel crop production is one way for urban neighbourhoods to reclaim vacant, blighted properties and also generate green energy for consumption. Combining soil classification data with urban development data, a GIS framework was developed to determine the amount of urban marginal land available in Pittsburgh, Pennsylvania. This location was chosen because small-scale sunflower crops are already being grown on urban marginal lands for biodiesel production. This paper evaluates two methods for identifying marginal lands for biofuel cultivation. The first is based on NRCS soil classifications derived from previous literature approaches. When compared with the locations of a non-profit that is actually cultivating marginal lands, the NRCS soil classification method captures less than 35% of the marginal lands being cultivated in Pittsburgh, and 2400 ha (6000 acres) of marginal land in total that could be used to grow sunflowers for biodiesel production. The authors modified the NRCS marginal soil classification method to include certain types of urban commercial lands and lands not currently classified as marginal, and created a framework that identifies almost 90% of the marginal lands currently under cultivation in Pittsburgh, with approximately 3500 ha (8700 acres) of available marginal lands. Pittsburgh's marginal lands could be used to produce up to 129,000 litres (34,100 gallons) of sunflower-based biodiesel. This could contribute a maximum of 0.1% to Pennsylvania's biofuel mandate and 0.003% to the RFS2. While a city's individual contribution may be incremental on the national scale, multiple cities and regions may be able to contribute to the RFS2. In addition, there is an unquantified social benefit that results from community engagement and revitalization, which is part of the mission of the Pittsburgh non-profit.

Geothermal energy

13/03539 A new conceptual model of the Icelandic crust in the Hengill geothermal area based on the indirect electromagnetic geothermometry

Spichak, V. V. *et al. Journal of Volcanology and Geothermal Research*, 2013, 257, 99–112.

Application of the indirect electromagnetic geothermometer calibrated by available temperature well logs has enabled the construction of the three-dimensional temperature model of the Hengill geothermal area (Iceland) up to a depth of 20 km. Its analysis showed that the background temperature of the Icelandic crust above 20 km does not exceed 400 °C. It is overlapped by a network of interconnected high-temperature low resistive channels, which braid through the crust mainly at a level of 10–15 km and root to a depth greater than 20 km. Accordingly, the probable heat sources feeding the geothermal system are supposed to be the intrusions of the hot partially molten magma upwelling from the mantle through faults and fractures. The comparison between the vertical temperature cross-sections and the projections of the earthquake hypocentres showed that they all are located in the areas where temperature does not exceed 400 °C, which is a gabbro solidus in a silica-rich Icelandic crust. Joint analysis of the temperature model together with the resistivity and residual Bouguer gravity anomalies enabled us to explain the distribution of the earthquake hypocentres by different geothermal regimes in adjacent parts of the area and cooling of large massifs of the partially molten solidified magma beneath seismically active areas. Based on the above inferences, the authors suggest a new self-consistent conceptual model of the Icelandic crust, which agrees with most of the previous geophysical results and provides an explanation for the facts that the previous models failed to explain.

13/03540 Analysis of thermal and dynamic comportment of a geothermal vertical U-tube heat exchanger

Bouhacina, B. *et al. Energy and Buildings*, 2013, 58, 37–43.

This paper presents a computational analysis on the turbulent flow and heat transfer for water flowing in a geothermal vertical U-tube heat exchanger (GHE). The governing equations, based on the k–ε model used to describe the turbulence phenomena, are solved by using finite volume method. The velocity and pressure terms of momentum equations are solved with SIMPLEC algorithm. The simulation of the dynamic and thermal behaviour of the geothermal vertical U-tube heat exchanger was carried out under Fluent software. Results are compared with recent work from the literature and good agreement is obtained. The evolution of temperature and the heat transfer according to time (700 h) and position, have been fixed, as well as the influence of fluid flow on the dynamic and thermal behaviour of the heat exchanger.

13/03541 Analytical approach to groundwater-influenced thermal response tests of grouted borehole heat exchangers

Wagner, V. *et al. Geothermics*, 2013, 46, 22–31.

For ground-source heat pump (GSHP) systems, the thermal response test (TRT) is commonly used to determine the heat transport parameters of the subsurface. The main limitation of this approach is the assumption of pure conductive heat transport, which might result in significant deviations. Based on the moving line source theory, a parameter estimation approach is introduced, which is sensitive to conduction and advection. This approach is calibrated and successfully tested against three different test cases. The presented analytical approach therefore expands the field of application of the TRT to advection-influenced conditions beyond a Darcy velocity of 0.1 m day^{-1}.

13/03542 Borehole resistance and vertical temperature profiles in coaxial borehole heat exchangers

Beier, R. A. *et al. Applied Energy*, 2013, 102, 665–675.

Ground source heat pump systems are often coupled to the ground by circulating a fluid through vertical borehole heat exchangers (BHEs). The design of a system requires estimates of the ground thermal conductivity and the borehole thermal resistance, which are usually determined by an *in situ* thermal response test on a completed borehole. The usual test interpretation methods average the inlet and outlet fluid temperatures and use this mean temperature as the average temperature along the borehole length. This assumption is convenient but does not strictly apply. For a coaxial heat exchanger this paper develops an analytical model for the vertical temperature profiles, which can be used instead of the mean temperature approximation to estimate borehole resistance. The model is verified with measured temperatures on a BHE, where an optical technique allows continuous measurements along a coaxial borehole during a distributed thermal response test. A sensitivity study shows that the proposed method corrects errors in the mean temperature approximation, which overestimates the borehole resistance in a coaxial borehole.

13/03543 Chemical and isotopic characteristics of geothermal fluids from Sulphur Springs, Saint Lucia

Joseph, E. P. *et al. Journal of Volcanology and Geothermal Research*, 2013, 254, 23–36.

Sulphur Springs is a vigorous, geothermal field associated with the active Soufrière volcanic centre in southern Saint Lucia, Lesser Antilles island arc. The 'Sulphur Springs Park' is an important tourist attraction (touted as the 'world's only drive-through volcano') with some of the hot pools being developed into recreational pools. Some 200,000 people visit the park each year. Since 2001, the hydrothermal fluids of Sulphur Springs have been sampled as part of an integrated volcanic monitoring programme for the island. Gas and water samples were analysed to characterize the geochemistry of the hydrothermal system, and to assess the equilibrium state and subsurface temperatures of the reservoir. This has also enabled us, for the first time, to establish baseline data for future geochemical monitoring. The gases are of typical arc-type composition, with N_2 excess and low He and Ar content. The dry gas composition is dominated by CO_2 (ranging from 601–993 mmol/mol), with deeper magmatic sourced H_2S-rich vapour undergoing boiling and redox changes in the geothermal reservoir to emerge with a hydrothermal signature in the fumarolic gases. Fluid contributions from magmatic degassing are also evident, mainly from the moderate to high contents of HCl and deeply-sourced H_2S gas, respectively. Sulphur Springs hydrothermal waters have acid-sulfate type compositions ($SO_4 = 78$–4008 mg/L; pH = 3–7), and are of primarily meteoric origin which have been affected by evaporation processes based on the enrichment in both $\delta^{18}O$ and δD ($\delta^{18}O = -1$ to 15‰ and $\delta D = -9$ to 14‰ respectively) in relation to the global meteoric water line (GMWL). These waters are steam-heated water typically formed by absorption of H_2S-rich gases in the near surface oxygenated groundwaters. Reservoir temperatures calculated from the evaluation of gas equilibria in the CO_2–CH_4–H_2 system reveal higher temperatures (190 to 300 °C) than those derived from quartz geothermometry (95 to 169 °C), which appeared to be affected by dilution with meteoric waters. Generally, no significant variations in fluid geochemistry of the hydrothermal system were observed between 2001 and 2006, and it is proposed that there were no changes in the state of volcanic activity during this period.

13/03544 'Derating factor' new concept for evaluating thermal performance of earth air tunnel heat exchanger: a transient CFD analysis

Bansal, V. *et al. Applied Energy*, 2013, 102, 418–426.

A new term 'derating factor' is devised for evaluating deterioration in thermal performance of earth air tunnel heat exchanger (EATHE) under transient operating conditions in predominantly hot and dry climate of Ajmer in India using experimental and computational fluid dynamics modelling with FLUENT software. Maximum air temperature drop obtained using steady state approach for EATHE of pipe length 100 m, pipe diameter 0.2 m and at air velocity of $5\,m\,s^{-1}$ is 18.4, 18.7 and 18.4 °C for soil thermal conductivity of 0.52, 2.0 and $4.0\,W\,m^{-1}\,K^{-1}$ respectively. However, the maximum air temperature drop obtained using transient approach during 24 h of operation vary between 18.3 and 14.0 °C, 18.3 and 17.2 °C, and 18.6 and 18.0 °C for soil thermal conductivity of 0.52, 2.0 and $4.0\,W\,m^{-1}\,K^{-1}$, respectively. The derating factor is found to be a function of thermal conductivity of soil, duration of continuous operation of EATHE and length of pipe. The analysed cases have shown the range of derating to be as minimal as 0.2% to as high as 68%, which if ignored while designing may lead to poor performance of earth air heat exchangers. Maximum value of derating factor is observed after continuous operation of EATHE for 24 h.

13/03545 Determination of optimal well trajectory during drilling and production based on borehole stability

Zare-Reisabadi, M. R. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2012, 56, 77–87.

Several studies have been done about borehole stability and optimized wellbore direction. However, the majority of them focused on stability during drilling, and there are only a few studies concerns with stability during drilling and production and its problems such as sanding simultaneously. This paper presents an analytical model that estimates collapse pressure in stability analysis during drilling and in addition determines maximum drawdown pressure to prevent sand production, using the Mogi–Coulomb failure criterion. The results show that in different *in situ* stress regimes, the inclination and azimuth have a significant role in wellbore stability during both drilling and production. Furthermore, the results show that the optimum direction for wellbore stability during drilling is also the best direction for stability of a production well. The analytical model is applied to field data in order to verify the applicability of the developed model.

13/03546 Geothermal heat pump systems: status review and comparison with other heating options

Self, S. J. *et al. Applied Energy*, 2013, 101, 341–348.

Heating is a major requirement in many regions, and growing energy demands and pollutant emissions have allowed unconventional heating technologies to be considered, including geothermal. Geothermal heat pumps are reviewed, including heat pump technology, earth connections, current world status and recent developments. Geothermal heat pump technology and conventional heating systems are compared in terms of costs, CO_2 emissions and other parameters. Geothermal heat pump use is economically advantageous when the price of electricity is low. Alternatively geothermal heat pump units have the lowest emissions depending when electricity is produced from a low emitting source.

13/03547 Hot water production improves the energy return on investment of geothermal power plants

Atlason, R. S. and Unnthorsson, R. *Energy*, 2013, 51, 273–280.

The aim of this study was to examine the energy efficiency at Nesjavellir geothermal power plant by calculating its energy return on investment (EROI). For calculations, real data were acquired from stakeholders on materials used in the construction, maintenance and operation of the plant. A previously proposed standard for EROI calculations is tested in this study. Also calculated is the energy payback time (EPT). The paper presents a new EROI metric which is given the name EROI ideal which looks at the maximum theoretical EROI, which shows the potential room for improvement in efficiency. Findings show that the infrastructure to deliver energy to Reykjavik is the largest contributor when looking at the embodied energy of used material. The power plant itself uses 12 MW of the produced 120 MW of electricity and 300 MW of hot water, which makes the plant itself the single largest energy consumer. $EROI_{3,}$i was found to be 32.4 over a 40-year lifetime, $EROI_{stnd}$ 33 and $EROI_{ide}$ 80.9. However, excluding hot water, the EROI dropped to 9.5. This indicates that the efficiency has not improved in electricity production using geothermal technology since the 1970s. Hot water production for domestic heating was therefore found to increase the EROI significantly.

13/03548 New geochemical investigations in Platanares and Azacualpa geothermal sites (Honduras)

Barberi, F. *et al. Journal of Volcanology and Geothermal Research*, 2013, 257, 113–134.

Platanares and Azacualpa geothermal sites of Honduras are located in an inner part of the Caribbean Plate far from the active volcanic front of Central America. Here geology indicates that there are not the conditions for the occurrence of shallow magmatic heat sources for high-enthalpy geothermal resources. Geothermal perspectives are related to the possibility of a deep circulation of meteoric water along faults and the storage of the heated fluid in fractured permeable reservoirs. Geochemical geothermometers indicate a temperature for the deeper part of the geothermal reservoir close to 200 °C for Platanares and of 150–170 °C for Azacualpa. Calcite scaling, with subordinate silica deposition has to be expected in both sites. CO_2 soil flux investigations have been carried out in both areas and reveal the presence of positive anomalies likely corresponding to the presence at depth of fractured degassing geothermal reservoirs. Compared with the geothermal areas of central Italy whose reservoirs are hosted in carbonate rocks, e.g. Latera, the CO_2 soil flux measured in Honduras is significantly lower (mean of 17 g/m^{2}day at Platanares and of 163 g/m^{2}day at Azacualpa) probably because of the dominant silicate nature of the deep reservoirs.

13/03549 Operation characteristics and experience of a ground source heat pump system with a vertical ground heat exchanger

Michopoulos, A. *et al. Energy*, 2013, 51, 349–357.

This article reports on the performance of a ground source heat pump system installed in a new municipality hall in northern Greece over an 8-year operation period. The system consists of a vertical ground heat exchanger, 21 boreholes in 80-m depth, 11 water-to-water heat pump units. Basic parameters of its operation are continuously monitoring by a data acquisition system. Based on these recordings, heat transfer flows from/to the building and the ground were calculated in order to estimate the performance of the system. It is found that the maximum ground heat exchanger load reaches 50 W/m in heating operation while in cooling mode it ranges between 20 and 210 W/m. The weekly performance factor of the heat pumps as well as the seasonal energy efficiency ratio were found to be between 5.0–6.2 and 4.5–5.5 in heating mode and 4.1–5.9 and 3.6–4.5 in cooling mode, respectively. Compared to a conventional heating and cooling system for this building, the ground source heat pump consumes 25.7% less primary energy and emits lower CO_2 and NO_x emissions by 22.7% and 99.6% respectively, but its SO_2 emissions are 18.4% higher.

13/03550 Performance analysis of Germencik geothermal power plant

Unverdi, M. and Cerci, Y. *Energy*, 2013, 52, 192–200.

The objective of this study is to calculate the efficiency of exergy in Germencik geothermal power plant, which has a power output of 47.4 MWe. As being the largest one in Turkey, this plant is operated by double-flash system which is based on the method of analysis of energy and exergy to evaluate its performance. The exergy analysis has been applied to the whole plant considering the first and the second laws of thermodynamics for each piece of equipment. In this study, by using the actual data values the losses of exergy have been determined and the flow diagram of exergy has been illustrated. When making calculations, the dead state temperature is accepted as 15 °C, and dead state pressure as 101.325 kPa s. The plant has seven production and six reinjection wells. From these production wells, geothermal fluid reaches the plant at an average temperature ranging from 194 to 214 °C, pressure of 23–30 bars and a total flow rate of 688.87 kg/s. An exergy input of 134,124 kW is obtained from these wells. The largest exergy input of 36,395 kW is obtained from OB-14 and this accounts for 27.1% of total exergy input. Moreover, major exergy losses and their exergy input account for 3.34% (4478 kW) for valves, 22.72% (30,477 kW) for high and low-pressure separation process during the decomposition of geothermal fluid, 5.1% (6837 kW) for turbine-generator during the conversion of steam into mechanic work, 9.41% (12,622 kW) for cooling tower, 5.53% (7414 kW) for internal use, and finally 22.68% (30,415 kW) for reinjection wells. Additionally, the second law efficiency of turbine-generator has been found to be 87.4% and the second law efficiency of overall plant has been found to be 35.34%. The obtained results have been given in tables and the largest loss of exergy has been determined to occur in separators.

13/03551 Power requirements of ground source heat pumps in a residential area

Bagdanavicius, A. and Jenkins, N. *Applied Energy*, 2013, 102, 591–600.

A study was undertaken to investigate the energy demand for space heating and domestic hot water systems as well as the electrical power requirement for heat pumps in residential dwellings. A residential area of 96 two-, three- and four-bedroom houses was considered. Energy demand and power requirements in old poorly insulated buildings and in new, well-insulated buildings were investigated. The requirement for electrical power for the heat pumps in the whole residential area was computed. The effect of room temperature settings, hot water use, heat pump thermal capacity and building insulation on the power requirements in the residential area was considered. It was found that hot water consumption has a significant effect on energy demand and power requirements. The energy demand for hot water systems may be up to 3.5 times higher than that for space heating for small, well-insulated buildings. A reduction of the room temperature setpoint and hot water consumption reduces average energy consumption. However, the peak power requirements are not significantly affected. Therefore a different control strategy, such as energy demand shifting, is needed in order to reduce electrical power peaks.

13/03552 Risk based lifetime costs assessment of a ground source heat pump (GSHP) system design: methodology and case study

Garber, D. *et al. Building and Environment*, 2013, 60, 66–80.

Space heating accounts for a large portion of the world's carbon dioxide emissions. Ground source heat pumps (GSHPs) are a technology which can reduce carbon emissions from heating and cooling. GSHP system performance is however highly sensitive to deviation from design values of the actual annual energy extraction/rejection rates from/to the ground. In order to prevent failure and/or performance deterioration of GSHP systems it is possible to incorporate a safety factor in the design of the GSHP by over-sizing the ground heat exchanger (GHE). A methodology to evaluate the financial risk involved in over-sizing the GHE is proposed is this paper. A probability based approach is used to evaluate the economic feasibility of a hypothetical full-size GSHP system as compared to four alternative heating ventilation and air conditioning (HVAC) system configurations. The model of the GSHP system is developed in the TRNSYS energy simulation platform and calibrated with data from an actual hybrid GSHP system installed in the Department of Earth Science, University of Oxford, UK. Results of the analysis show that potential savings from a full-size GSHP system largely depend on projected HVAC system efficiencies and gas and electricity prices. Results of the risk analysis also suggest that a full-size GSHP with auxiliary back up is potentially the most economical system configuration.

13/03553 Single and double U-tube ground heat exchangers in multiple-layer substrates

Florides, G. A. *et al. Applied Energy*, 2013, 102, 364–373.

The efficiency of ground-source heat pumps depends on the correct sizing of the associated ground heat exchangers (GHEs). Multiple ground layers with regard to GHE and the presence of more than one loops in each borehole (multiple U-tubes) are sparsely raised in the literature. Therefore the accurate prediction of the performance of the GHE under these conditions is of fundamental importance. A newly developed and validated model is applied to a multiple layer ground regime with different properties and the effect of the layer sequence on the outlet temperature is examined. The model is also modified to allow the study of a double U-tube GHE in a single borehole and the assessment of its efficiency with regard to its building cost. Various configurations are then compared to show that an in-series double GHE is the most efficient. The numerical model developed for energy flows and temperature changes in and around a borehole, when a fluid circulates through single and double U-tubes, is validated upon comparing its results with established experimental results for a single GHE. This model is an improvement of a previous one, based on the time-dependent convection–diffusion equation.

13/03554 Specifics of integration of wind power plants into the Croatian transmission network

Capuder, T. *et al. Applied Energy*, 2013, 101, 142–150.

Increasing number and capacity of wind turbines have overgrown connection to the distribution network. Considerable wind power plant installed capacity makes their connection to the transmission network a common practice today. However, large-scale wind power integration requires increase in transmission network capacity. The problem with transmission network capacity investments is that they will be fully utilized only on rare occasions. This makes the investments in power lines reinforcement economically questionable. The transmission network capacity problems get even worse when several large wind power plants with simultaneous peaks in production are connected to the transmission network in the same node. The objective of this paper is to provide an insight in the issues of large-scale wind power plant integration into the transmission grid in Croatia. An accurate and detailed model for assessing power flows and voltage levels has been developed as a result of multiple projects involving wind power plant connections to the Croatian transmission network. The presented model emphasizes the importance of reversible hydro power plants for potential energy storage of wind energy. For a more detailed conclusion a dynamic analysis should be conducted including the specifics of each generator and wind turbines to be installed in the future. The model also demonstrates inadequacy of the 220 kV network for evacuation of future wind power. Despite the open access policy to all investors, the authors find the deep connection policy currently applied in Croatia to be somewhat discriminatory depending on the location of future power plant. Based on European experiences a mixed connection cost policy has been suggested. This policy clearly shows a less discriminatory approach to future investors and increases the feasibility of certain future wind projects.

13/03555 Structure of hydrothermal convection in the Upper Rhine Graben as inferred from corrected temperature data and basin-scale numerical models

Guillou-Frottier, L. *et al. Journal of Volcanology and Geothermal Research*, 2013, 256, 29–49.

Geothermal anomalies in sedimentary basins are strongly controlled by fluid circulation within permeable zones. Exploration of new targets requires the understanding of how and why hydrothermal circulation patterns establish in a particular zone. This study presents a new compilation of newly corrected bottom-hole temperature data in the French part of the Upper Rhine Graben, where the Soultz-sous-Forêts temperature anomaly is locked beneath a local horst structure. After a geostatistically constrained interpolation procedure, maps and cross-sections are extracted from the three-dimensional thermal block, together with the associated standard deviations. Thermal anomalies are preferentially associated with the thickest zones of the permeable fractured Buntsandstein (sandstones) formation, in apparent contradiction with previous models where two major fault zones were suggested to control fluid flow. The underlying fractured granitic basement hosts fluid circulation patterns which are apparently controlled at large-scale by the inclined basement–sediments interface. Based on these observations, numerical models of hydrothermal convection including an inclined basement–sediments interface, a local horst structure, and realistic petrophysical properties have been carried out. The depth-decrease of permeability, the inclination of the interface and the fixed heat flow condition at the base of the model, explain why only a few upwellings can be triggered. Thermal anomalies and a measured temperature profile can be reproduced when fault permeability equals $10^{-14}\,m^2$. Interestingly, structure of convective patterns also exhibits a second and hotter upwelling, in the Rittershoffen area, 8 km east of the Soultz-sous-Forêts upwelling zone, where another geothermal exploration project is now underway. The understanding of hydrothermal convection with realistic fluid and rock properties clearly appears as a predictive tool for geothermal exploration strategies.

13/03556 Sustainable heat farming: modeling extraction and recovery in discretely fractured geothermal reservoirs

Fox, D. B. *et al. Geothermics*, 2013, 46, 42–54.

Although many natural hydrothermal geothermal systems have been shown to be productive over long periods of time, limited field testing of enhanced or engineered geothermal systems (EGS) has prevented adequate assessment of their sustainability. To estimate how renewable EGS reservoirs might be, an analytical approach employing Green's function was used to model transient thermal conduction in an idealized reservoir containing a single rectangular fracture to evaluate heat transfer effects during alternating periods of extraction and recovery. During recovery, the temperature along the fracture surface approaches the temperature of the bulk rock with the deviation from the surrounding bulk temperature decaying as $1/\sqrt{t}$ where t is the recovery time. Numerical simulations of a multiple parallel fracture reservoir using the TOUGH2 code agreed with the derived analytical solutions over a range of flow rates and interfracture spacings with only small deviation due to multidimensional effects. Multidimensional effects are more pronounced near the inlet and outlet of the fracture and are reduced at higher flow rates. Thermal interactions between sufficiently spaced fractures are negligible for production periods of 10–30 years, suggesting that the single fracture analytical model can be applied to multifracture reservoirs provided that the mass flow used is on a per fracture basis. Simulation results show that multifracture EGS reservoirs have a greater capacity to sustain high outlet temperatures, suggesting that conductively dominated EGS systems can be regarded as renewable over time scales of societal utilization systems (three to five times the heat extraction time).

13/03557 The cooling seasonal performance factor of a hybrid ground-source heat pump with parallel and serial configurations

Park, H. *et al. Applied Energy*, 2013, 102, 877–884.

A hybrid ground-source heat pump (HGSHP) is proposed to overcome the decrease in the performance of a ground-source heat pump (GSHP) at the degraded ground thermal condition. In this study, a performance comparison between the GSHP and the HGSHP with parallel and serial configurations was conducted by varying the leaving fluid temperature (LFT) of the ground heat exchanger (GHEX), the fluid flow rate of the supplemental loop, the mean outdoor bin temperature, and the switching temperature of the hybrid operation. At the LFT of the GHEX of 40 °C, the coefficient of performances (COPs) for the HGSHP with the parallel and serial configurations were 18% and 6% higher than that of the GSHP, respectively. The cooling seasonal performance factors (CSPFs) of the HGSHPs with the parallel and the serial configurations were 6.5% and 2.0% higher, respectively, than that of the GSHP for Daegu city in South Korea.

13/03558 The effect of borefield geometry and ground thermal load profile on hourly thermal response of geothermal heat pump systems

Fossa, M. and Minchio, F. *Energy*, 2013, 51, 323–329.

Vertical borehole heat exchangers (BHE) are a common solution for ground coupled heat pump (GCHP) applications. Correct BHE design and sizing are mandatory to either assure long-term GCHP performance or reduce the payback period. Most models for performing the time varying analysis of complex borefields are based on the solution of the conduction equation, through the calculation of proper temperature response factors. The duct storage tool (DST) is often referred as the benchmark analysis tool, even if it is based on a simplified description of the borefield geometry. In this paper, DST predictions, in terms of hourly fluid temperatures along 20 years, are compared with the corresponding results obtained by implementing the multiple aggregation algorithm (MLAA) approach into a model able to employ suitable *g*-functions generated starting from the finite line source solution. This paper discusses some aspects of the improvements here introduced to the original MLAA method. The study compares the predicted fluid temperature values by the DST and MLAA models, with special attention to the influence of the BHE geometry (matrix like vs in line configurations) and to the shape of the yearly hourly load profiles (balanced vs unbalanced ground loads).

13/03559 Three dimensional temperature simulation from cooling of two magma chambers in the Las Tres Vírgenes geothermal field, Baja California Sur, Mexico

Guerrero-Martínez, F. J. and Verma, S. P. *Energy*, 2013, 52, 110–118.

A three-dimensional numerical model is proposed for natural state simulation of the Las Tres Vírgenes (LTV) geothermal system from emplacement and cooling of the heat source. A conceptual model of the LTV volcanic system was developed considering tectonic regime, structural geology, outcropping geology, eruptive events and geochronology. The model includes the emplacement of two magma chambers, lateral variations of physical properties and the topography of the geographic area. Model calibration was carried out for several chamber volumes and depths, as well as thermal diffusivity of lithological units. Static formation temperatures and homogenization temperatures were used as references. Chamber depths between 3000 and 3500 m below sea level with total chamber volumes of 429 and 563 km^3, respectively, were inferred from the simulation results. The exergy of the reservoir was consistent with the current installed capacity of the power plant (10 MWe); however, an increase of at least 4 MWe would be attained with optimized power cycles.

13/03560 Transient analysis based determination of derating factor for earth air tunnel heat exchanger in winter

Misra, R. *et al. Energy and Buildings*, 2013, 58, 76–85.

Thermal performance of earth air tunnel heat exchanger (EATHE) under transient operating conditions in winter season has been evaluated for predominantly hot and dry climate of Ajmer (India) using experimental and computational fluid dynamics (CFD) modelling. Effect of time duration of continuous operation and thermal conductivity of soil on thermal performance of EATHE under transient conditions has been analysed. Results show that the transient thermal performance of EATHE is significantly dependent on thermal conductivity of the soil and duration of its continuous operation. Under steady state condition, a rise of 19.6 °C is obtained in air passing through EATHE having 0.1 m diameter and 60 m length, at 5 m/s flow velocity, whereas, the transient analysis shows that for soil having thermal conductivity of 0.52 W m^{-1} K^{-1}, the heating of air reduces from 19.4 to 17.2 °C, after 24 h of continuous operation. Heating effect after 24 h of operation for soil thermal conductivity of 2.0 and 4.0 W m^{-1} K^{-1}, reduced from 19.6 to 19.2 °C and 19.6 to 19.5 °C, respectively. The analysed cases have shown the range of derating to be as minimal as 0% to as high as 64%, which if ignored while designing may lead to poor performance of earth air heat exchangers.

Solar energy

13/03561 A hybrid solar and chemical looping combustion system for solar thermal energy storage

Jafarian, M. *et al. Applied Energy*, 2013, 103, 671–678.

A novel hybrid of a solar thermal energy and a chemical looping combustion (CLC) system is proposed here, which employs the oxygen carrier particles in a CLC system to provide diurnal thermal energy storage for concentrated solar thermal energy. In taking advantage of the chemical and sensible energy storage systems that are an inherent part of a CLC system, this hybrid offers potential to achieve cost effective, base load power generation for solar energy. In the proposed system, three reservoirs have been added to a conventional CLC system to allow storage of the oxygen carrier particles, while a cavity solar receiver has been chosen for the fuel reactor. The performance of the system is evaluated using ASPEN PLUS software, with the model being validated using independent simulation result reported previously. Operating temperature, solar efficiency, solar fraction, exergy efficiency and the fraction of the solar thermal energy stored for a based load power generation application are reported.

13/03562 A study on thermal performance, thermal comfort in sleeping environment and solar energy contribution of solar Chinese Kang

He, W. *et al. Energy and Buildings*, 2013, 58, 66–75.

Solar Chinese Kang, which combines Chinese Kang with solar water collectors, can provide an alternative in terms of sustainable and energy-efficient heating systems for rural homes in northern China. A mathematical model of solar Chinese Kang is presented to study its thermal performance and energy consumption based on the evaluation of sleeping environment thermal comfort with predicted mean vote (PMV) value. A test rig is built and the analytic model has been validated through the experimental data before it is used to optimize the operation model. The research results show that when inlet water temperature of solar Chinese Kang varies from 35 to 55 °C, the PMV of sleeping environment is acceptable. The solar fraction (SF) can reach 74.3% when inlet water temperature is 35 °C in one case study, and when inlet water temperature is 55 °C, the SF is 52.6%, which is lower than 74.3%. However, the corresponding PMV is higher and warmer sleeping environment can be supplied.

13/03563 A support strategy for the promotion of photovoltaic uses for residential houses in Korea

Oh, S.-D. *et al. Energy Policy*, 2013, 53, 248–256.

Various policies such as feed-in tariffs, quota obligations and capital subsides were enacted to expand the uses of renewable energy (RE) in many countries. This study examined whether capital subsidies are cost effective in relation to the installation of solar photovoltaic (PV) facility. To do this, the capacity factor, which is one of the crucial factors for determining the unit cost of electricity from a solar PV system, was estimated from the monthly average clearness index data collected at various cities in Korea. Thermoeconomic analysis was applied to calculate the unit cost of electricity based on the calculated capacity factor of the solar PV system. Instead of subsidizing the same percentage of the capital cost of each PV system installation, it is reasonable for the government to adopt a measure to match the subsidy paid to the payback period of the initial investment for all 5 million potential solar PV users in Korea.

13/03564 Actual performance and characteristic of a grid connected photovoltaic power system in the tropics: a short term evaluation

Khatib, T. *et al. Energy Conversion and Management*, 2013, 71, 115–119.

This paper presents a field operation experience for a grid-connected photovoltaic (PV) system under tropical climate. The system is consisted of a 5 kWp PV array and a 6 kW DC/AC inverter. The operation performance data are recorded in order to develop accurate mathematical models for the system as well as to evaluate the productivity of the system. The experiment results show that, the average PV performance (the ratio of the theoretical performance to the actual performance) is 73.12% while the average inverter performance (the ratio of the theoretical inverter efficiency to the actual inverter efficiency) is 98.56%. Moreover, it is found that the daily yield factor of the PV system is 2.51 kW h/kWp day while, the capacity factor is 10.47%. However, it is concluded that the productivity of the system is below the prospected rate and thus, an inspection of the system must be done in order to diagnose the problem of the system's low productivity. This paper presents worthwhile information for those who are interested in PV system installation in Malaysia and nearby country.

13/03565 An assessment of the optimal timing and size of investments in concentrated solar power

Massetti, E. and Ricci, E. C. *Energy Economics*, 2013, 38, 186–203.

The authors have extended the WITCH model to consider the possibility to produce and trade electricity generated by large-scale concentrated solar power plants (CSP) in highly productive areas that are connected to demand centres through high voltage direct current cables. They have tested the attractiveness of the CSP option by imposing a global cap on greenhouse gas concentration equal to 535 ppm CO_2-eq in 2100, with and without constraints to the expansion of nuclear power and IGCC coal with carbon capture and storage (CCS). It was found that it becomes optimal to produce with CSP from 2040 and to trade CSP electricity across the Mediterranean from 2050. Therefore projects like DESERTEC seem to be premature. After 2050, CSP electricity shares become significant. CSP has a high stabilization cost option value: depending on the constraints, it ranges between 2.1% and 4.1% of discounted GDP in the Middle East and North Africa (MENA), between 1.1. and 3.4 in China, between 0.2% and 1.2% in the USA, between 0.1 and 1.3% in Eastern Europe and between 0.1 and 0.4% in Western Europe. A moderate level of subsidy to invest more and earlier in CSP might increase welfare. However, large-scale deployment should occur after 2040. The authors also show that MENA countries have the incentive to form a cartel to sell electricity to Europe at a price higher than the marginal cost. This suggests that a hypothetical Mediterranean market for electricity should be carefully regulated.

13/03566 An efficient thiolate/disulfide redox couple based dye-sensitized solar cell with a graphene modified mesoscopic carbon counter electrode

Liu, G. *et al. Carbon*, 2013, 53, 11–18.

Graphene sheet is used to modify mesoscopic carbon materials through electrostatic induced self-assembly and applied as a Pt-free counter electrode (CE) in a thiolate/disulfide redox couple based dye-sensitized solar cell (DSSC). The electrochemical characterization are carried out with Electrochemical impedance spectroscopy and Tafel polarization, which indicates that the catalytic activity of mesoscopic carbon CE is dramatically improved and the mass transport of the thiolate/disulfide redox couple in the pores of mesoscopic carbon electrode was accelerated via being modified with graphene. As a result, efficiency up to 6.55% is obtained, which is increased by 35% than that of the normal mesoscopic carbon CE. It could be expected that Pt-free graphene modified mesoscopic carbon materials promise tremendous potential for iodine-free DSSC.

13/03567 An experimental investigation on a multilevel inverter for solar energy applications

Chinnaiyan, V. K. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 157–167.

The main objective of this work is to design, develop and test a three phase multilevel inverter with the modern power electronic switches to reduce the power quality issues in solar power conversion systems. Due to the increased usage of power electronic converters for processing power, power quality has become an important research topic. As the power level increases, the voltage level is increased accordingly to obtain satisfactory efficiency. The multilevel power converter has shown growing popularity. The fundamental advantages of multilevel converter topologies are low distorted output waveforms and limited voltage stress on the switching devices and hence the reduced electromagnetic interferences. The main disadvantages are higher complexity and more difficult control; it can be overcome by using modern digital controllers. In this paper, the performance parameters are analysed with the developed prototype of the three-phase cascaded multilevel inverter for solar energy conversion designed with digital controller for reduced power quality issues with three phase AC motor drive. The main objective is to obtain the better quality of output waveform on the inverter output with suitable control strategy on the experimental hardware setup.

13/03568 An exploratory study of the solar thermal electrolytic production of Mg from MgO

Sheline, W. *et al. Energy*, 2013, 51, 163–170.

The electrolytic production of Mg from MgO was experimentally and theoretically investigated near 1550 K. The experimental work was carried out in a SiC electrolytic cell housed in a 10 kW solar receiver that was located at the focal point of a concentrating solar furnace. The oxide was dissolved in either CaF_2 or MgF_2. The cathode was Mo and the anode was either Pt or $C_{graphite}$. Mg evolved as a gas, was quenched on cooling coils at the exit of the reactor and was collected for analysis. A thermodynamic cycle study indicates that the ideal thermal efficiency for the solar process is 35% for an inert anode and 39% for a carbon anode. Experimental results from both current-cell potential traces and X-ray diffraction verify the successful electrolysis of MgO and the production of Mg. The experimental decomposition potential of the oxide was near the expected thermodynamic value. As expected, the experimental decomposition potential was reduced when carbon replaced the inert anode. In the experiment with Pt as the anode and MgF_2 as the solvent, a current efficiency of 14% was measured.

13/03569 Computational studies on a latent thermal energy storage system with integral heat pipes for concentrating solar power

Nithyanandam, K. and Pitchumani, R. *Applied Energy*, 2013, 103, 400–415.

Latent thermal energy storage system (LTES) is an effective technique for storing solar energy and load management with advantages including isothermal operation and high-energy storage density. However, the low thermal conductivity of the phase change material (PCM) in a LTES reduces the melting and solidification rates of the PCM, which is sought to be increased for a viable operation of the energy storage system. This paper investigates an approach to reducing the thermal resistance of PCM through embedded heat pipes which are passive heat transfer devices that efficiently transfer large amount of thermal energy between the phase change material and a heat transfer fluid (HTF). A transient three-dimensional computational analysis of a shell-and-tube LTES embedded with heat pipes is performed for melting (charging) and solidification (discharging) to determine the position of melt front, energy stored and effectiveness of the heat pipe embedded configurations as a function of time. The influence of the number and orientation of heat pipes and the configuration of the system are analysed to identify designs that lead to improved effectiveness.

13/03570 Cyclic operation of molten-salt thermal energy storage in thermoclines for solar power plants

Yang, Z. and Garimella, S. V. *Applied Energy*, 2013, 103, 256–265.

The cyclic operation of molten-salt thermal energy storage thermoclines for solar thermal power plants is systematically investigated. A comprehensive, two-temperature model is first developed for the cyclic operation of a thermocline operating with a commercially available molten salt as the heat transfer fluid and quartzite rock as the filler. Volume-averaged mass and momentum equations are employed, with the Brinkman–Forchheimer extension to the Darcy law used to model the porous-medium resistance. Energy equations for the molten salt and the filler are coupled by an interstitial Nusselt number representing the heat transfer between the phases. A finite-volume approach is employed to solve the governing equations. The model is validated against experiments from the literature and then used to systematically study the cyclic behaviour of the thermocline thermal storage system. Thermal characteristics including temperature profiles and cycle efficiency are explored. Guidelines are developed for designing the dimensions and molten salt flow rates for solar thermocline systems of different power capacities. The cycle efficiency is found to be improved at smaller melt Reynolds numbers, larger length ratios (molten salt flow distance in a half-cycle to the filler particle diameter) and larger tank heights. The filler particle diameter and the tank volume are found to strongly influence the cycle efficiency.

13/03571 Design and modeling of a photovoltaic thermal collector for domestic air heating and electricity production

Touafek, K. *et al. Energy and Buildings*, 2013, 59, 21–28.

Hybrid photovoltaic thermal (or simply PV/T) collectors are devices that simultaneously convert solar energy into electricity and heat. The improving of the electrical efficiency, by reducing the photovoltaic collector's temperature, as well as taking advantage of the thermal energy produced, constitutes the basic idea in the development of hybrid PV/T collectors. A new design of hybrid collectors for air heating is presented in this paper. The theoretical study is carried out through the numerical modelling, and the results of the simulation are integrally developed; witch a prototype is realized. Experimental validation of the mathematical model as well as the study of the thermal and electric performance is detailed. The application of this new design has given a good thermal and electric performance compared to the traditional hybrid collectors. Its simplicity of implementation and its easy integration in buildings make them more competitive.

13/03572 Design guidelines for thermo-photo-voltaic generator: the critical role of the emitter size

Attolini, G. *et al. Applied Energy*, 2013, 103, 618–626.

In the past decade, the thermophotovoltaic (TPV) generator has gained an increasing attention as cogeneration system for the distributed generation sector. Nevertheless, these systems are not fully developed and studied: several aspects need to be further investigated and completely understood. The aim of this study is to highlight and outline the main design guidelines for a TPV generator with a specific attention to the emitter section. More in details, an investigation of the role of the emitter size will be developed by considering its influence on spectral efficiency (defined as the ratio between the emitted radiation in the useful range for photovoltaic conversion and the introduced power with fuel); by using simplified assumptions, the spectral efficiency as a function of the emitter area in four different TPV configurations will be estimated. The achieved results show specific power values per unit emitter area significantly larger than in prototypes realized up to date. Further, the developed analysis allows to show the role of the optical filter and of the air pre-heating exchanger in order to increases the spectral efficiency of the system, being equal the considered power density.

13/03573 Electrical power fluctuations in a network of DC/AC inverters in a large PV plant: relationship between correlation, distance and time scale

Perpiñán, O. *et al. Solar Energy*, 2013, 88, 227–241.

This paper analyses the correlation between the fluctuations of the electrical power generated by the ensemble of 70 DC/AC inverters from a 45.6 MW PV plant. The use of real electrical power time series from a large collection of photovoltaic inverters of a same plant is an important contribution in the context of models built upon simplified assumptions to overcome the absence of such data. This data set is divided into three different fluctuation categories with a clustering procedure which performs correctly with the clearness index and the wavelet variances. Afterwards, the time dependent correlation between the electrical power time series of the inverters is estimated with the wavelet transform. The wavelet correlation depends on the distance between the inverters, the wavelet time scales and the daily fluctuation level. Correlation values for time scales below 1 minute are low without dependence on the daily fluctuation level. For time scales above 20 min, positive high correlation values are obtained, and the decay rate with the distance depends on the daily fluctuation level. At intermediate time scales the correlation depends strongly on the daily fluctuation level. The proposed methods have been implemented using free software. Source code is available as supplementary material.

13/03574 Electricity demand savings from distributed solar photovoltaics

Glassmire, J. *et al. Energy Policy*, 2012, 51, 323–331.

Due largely to recent dramatic cost reductions, photovoltaics (PVs) are poised to make a significant contribution to electricity supply. In particular, distributed applications of PV on rooftops, brownfields, and other similar applications – hold great technical potential. In order for this potential to be realized, however, PV must be 'cost-effective' – that is, it must be sufficiently financially appealing to attract large amounts of investment capital. Electricity costs for most commercial and industrial end-users come in two forms: consumption (kW h) and demand (kW). Although rates vary, for a typical larger commercial or industrial user, demand charges account for about ~40% of total electricity costs. This paper uses a case study of PV on a large university campus to reveal that even very large PV installations will often provide very small demand reductions. As a result, it will be very difficult for PV to demonstrate cost-effectiveness for large commercial customers, even if PV costs continue to drop. If policymakers would like PV to play a significant role in electricity generation – for economic development, carbon reduction, or other reasons – then rate structures will need significant adjustment, or improved distributed storage technologies will be needed.

13/03575 Energy management strategy for solar-powered high-altitude long-endurance aircraft

Gao, X.-Z. *et al. Energy Conversion and Management*, 2013, 70, 20–30.

Development of solar-powered high-altitude long-endurance (HALE) aircraft has a great impact on both military and civil aviation industries since its features in high-altitude and energy source can be considered inexhaustible. Owing to the development constraints of rechargeable batteries, the solar-powered HALE aircraft must take amount of rechargeable batteries to fulfil the energy requirement in night, which greatly limits the operation altitude of aircraft. In order to solve this problem, a new energy management strategy (EMS) is proposed based on the idea that the solar energy can be partly stored in gravitational potential in daytime. The flight path of HALE aircraft is divided into three stages. During the stage 1, the solar energy is stored in both lithium–sulfur battery and gravitational potential. The gravitational potential is released in stage 2 by gravitational gliding and the required power in stage 3 is supplied by lithium–sulfur battery. Correspondingly, the EMS is designed for each stage. The simulation results show that the aircraft can always keep the altitude above 16 km with the proposed EMS, and the power consumed during night can be also alleviated. Comparing with the current EMS, about 23.5% energy is remained in batteries with the proposed EMS during one day–night cycle. The sensitivities of the improvement of crucial technologies to the performance of aircraft are also analysed. The results show that the enhancement of control and structural system, lithium–sulfur battery, and solar cell are ranked in descending order for the performance improvement of solar-powered HALE aircraft.

13/03576 Enhancing solar hydrogen production via modified photochemical treatment of Pt/CdS photocatalyst

Yao, W. *et al. Catalysis Today*, 2013, 199, 42–47.

A modified photoetching process is found to significantly improve the photocatalytic activity of Pt/CdS photocatalyst for solar hydrogen production. The photoetching process was carried out by dispersing Pt/CdS photocatalyst particles in an aqueous ammonium sulfite ($(NH_4)_2SO_3$) solution under a vacuum-degassed condition. The Pt/CdS particles were then exposed to photo-radiation (350–800 nm) for 20 h. The rate of hydrogen production via visible light photooxidation of aqueous $(NH_4)_2SO_3$ solution over the photochemically treated Pt/CdS is about 130 times higher than that of untreated Pt/CdS samples. Effects of platinum loading technologies on the photocatalytic activity of Pt/CdS photocatalyst for hydrogen production are also investigated in this paper. Photochemically deposited Pt/CdS photocatalyst in an aqueous ammonium sulfite solution has shown a 100% increase in hydrogen production rate over that of photocatalysts traditionally photo-platinized in an aqueous glacial acetic acid solution. The prepared catalysts are characterized using XRD, FESEM, TEM, BET and XPS techniques and the changes of Pt particle size and surface elementary states of Cd and S are observed before and after the photoetching process.

13/03577 Estimating Arizona residents' willingness to pay to invest in research and development in solar energy

Mueller, J. M. *Energy Policy*, 2013, 53, 462–476.

This study estimates Arizona residents' willingness to pay (WTP) to invest in a solar energy research and development fund using data obtained from a dichotomous-choice contingent valuation mail survey. The authors examine differences in WTP estimates using different categorizations for respondent uncertainty. They also employ both commonly used maximum likelihood and less frequently applied Bayesian estimation techniques. Respondent uncertainty was found to have an economically significant impact on WTP estimates, while WTP estimates are robust to different estimation techniques. The robust specification with strict uncertainty coding indicates the average Arizona household is willing to pay approximately $17 per month to invest in research and development in solar energy.

13/03578 Exergetic analysis of a biodiesel production process from *Jatropha curcas*

Blanco-Marigorta, A. M. *et al. Applied Energy*, 2013, 101, 218–225.

Biodiesel is considered as an environmentally friendly renewable diesel fuel alternative. The interest in using *Jatropha curcas* as a feedstock for the production of biodiesel is that it grows rapidly. Oil from *J. curcas* does not compete with the food sector due to its toxic nature and it can be cultivated in marginal/poor soil. Also, its price is low and stable. In the past decade, the investigation on biodiesel production was centred on the choice of the suitable raw material and on the optimization of the process operation conditions. Nowadays, research is focused on the improvement of the energetic performance and on diminishing the inefficiencies in the different process components. The method of exergy analysis is well suited for furthering this goal, for it is a powerful tool for developing, evaluating and improving an energy conversion system. This study identifies the location, magnitude and sources of thermodynamic inefficiencies in a biodiesel production process from *J. curcas* by means of an exergy analysis. The thermodynamic properties were calculated from existing databases or estimated when necessary. The higher exergy destruction takes places in the transesterification reactor due to chemical reactions. Almost 95% of the exergy of the fuel is destroyed in this reactor. The exergetic efficiency of the overall process is 63%.

13/03579 Extraction of maximum power point in solar cells using bird mating optimizer-based parameters identification approach

Askarzadeh, A. and Rezazadeh, A. *Solar Energy*, 2013, 90, 123–133.
The maximum power point of solar cells can be extracted by knowing the values of the electrical parameters. The validity of the obtained result depends on the accuracy of the model parameters. Hence, it is important to use a superior optimization technique to identify the optimal values of the parameters. Recently, a metaheuristic optimization algorithm, bird mating optimizer (BMO), has been devised which tries to metaphorically imitate the mating strategies of bird species. BMO employs several searching patterns to explore the region under consideration. This ability helps the algorithm to maintain the diversity and avoid premature convergence, and therefore, get close to the global solution. In this paper, the electrical parameters of a 57 mm diameter commercial (RTC France) silicon solar cell are identified using BMO. The optimal parameters are then used to extract the maximum power point of the system. The accuracy of the proposed parameter identification approach is compared with the results found by the other optimization techniques. Simulation results accentuate the superior potential of BMO algorithm.

13/03580 Introducing the best model for predicting the monthly mean global solar radiation over six major cities of Iran

Khorasanizadeh, H. and Mohammadi, K. *Energy*, 2013, 51, 257–266.
In this study, by using long-term global solar radiation data and other meteorological parameters, 11 empirical models taken from the literature were tested for prediction of monthly mean daily global solar radiation over six major cities of Iran, named Isfahan, Karaj, Mashhad, Shiraz, Tabriz and Tehran. The models are from three categories: (1) only function of sunshine duration; (2) function of sunshine duration as well as relative humidity and ambient temperature; (3) independent of sunshine duration and function of relative humidity, ambient temperature and its maximum and minimum. The models were established using statistical regression technique and their accuracies evaluated using the statistical indicators of mean percentage error (MPE), mean bias error (MBE) and root mean square error (RMSE); hence the best model in each category was recognized. Although, five out of the six nominated cities fell in climatic classification of BSk, it was not possible to introduce a single model even for the cities having the same climate type. However, for all of the cities the best model was either from categories (1) or (2). In line with increased tendency toward installation of solar systems in Iran, the proposed models are useful for simulations and incorporation in design procedures.

13/03581 Lessons from photovoltaic policies in China for future development

Huo, M.-l. and Zhang, D.-w. *Energy Policy*, 2012, 51, 38–45.
The first provides an overview of the current status of photovoltaic (PV) industry development in China, including the penetration speed, the market segments and the value chain. PV power is an inevitable choice for China to ensure energy security and to facilitate greenhouse gas mitigation. China's PV industry has made significant progress since 2006, after the renewable energy law laid a legal foundation for deployment policy making and private investment. The government designed different kinds of incentives according to the characteristics of different market sectors, including capital subsidy, net metering, and feed-in tariffs. Meanwhile the central and local governments encouraged PV R&D and new plant investments so as to drive PV cost reduction and economic development. However, there are a number of problems. The market incentive scheme, public R&D, technical standards, and grid integration impede the sustainable development of PV technology in China. In order to resolve these problems, the authors recommend designing predetermined degression of incentives, organizing public R&D for a concrete target of cost reduction, coordinating local manufacturing policies at the central level, improving the institutions of grid integration, and encouraging international cooperation.

13/03582 Mathematical modeling of solar chimney power plants

Koonsrisuk, A. and Chitsomboon, T. *Energy*, 2013, 51, 314–322.
The solar chimney power plant is a system with promise to generate electrical power from free solar energy. In this study, a solar collector, chimney and turbine are modelled together theoretically, and the iteration techniques are carried out to solve the resulting mathematical model. Results are validated by measurements from an actual physical plant. Moreover, the model is employed to predict the performance characteristics of large-scale commercial solar chimneys, indicating that the plant size, the factor of pressure drop at the turbine, and solar heat flux are important parameters for performance enhancement. In addition, the study proposes that the most suitable plant, affordable by local government standards to respond to the electricity demand of a typical village in Thailand, is the one with a collector radius and chimney height of 200 and 400 m, respectively. Furthermore, it is shown that the optimum ratio between the turbine extraction pressure and the available driving pressure for the proposed plant is approximately 0.84. A simple method to evaluate the turbine power output for solar chimney systems is also proposed in the study using dimensional analysis.

13/03583 Optimal operation of a solar-thermal power plant with energy storage and electricity buy-back from grid

Lizarraga-Garcia, E. *et al. Energy*, 2013, 51, 61–70.
The optimization of time-variable operation to maximize revenue through selling and purchasing electricity to/from the grid is presented for a thermal energy storage system. Time-variable electricity prices and electricity buy-back from the grid to re-charge the energy storage is considered by adding electric heaters to the CSPonD concept. Three case studies are considered: (i) time-variable operation without electrical heating under time-invariant electricity price; (ii) operation under time-variant electricity price without electric heaters; (iii) operation under time-variant electricity price allowing charging of the pond using the grid electricity. These demonstrate the effect of time-invariant versus time-of-use feed-in-tariff. Two hourly price profiles are considered, representing a moderately and highly fluctuating price profile respectively. Uncertainty of the cost function is indirectly addressed: the approach optimizes for the expected value of profit. The results show significant increase in the revenue when adding electric heaters. Under the moderately fluctuating electricity price, the use of heaters increases the revenue significantly, compared to the same case with no electric heaters considered. In the case of highly fluctuating electricity price, the use of heaters more than doubles the revenue.

13/03584 Optofluidic solar concentrators using electrowetting tracking: concept, design, and characterization

Cheng, J. *et al. Solar Energy*, 2013, 89, 152–161.
This paper introduces a novel optofluidic solar concentration system based on electrowetting tracking. With two immiscible fluids in a transparent cell, the orientation of fluid–fluid interface can be actively controlled via electrowetting. The naturally formed meniscus between the two liquids can function as a dynamic optical prism for solar tracking and sunlight steering. An integrated optofluidic solar concentrator can be constructed from the liquid prism tracker in combination with a fixed and static optical condenser (Fresnel lens). Therefore, the liquid prisms can adaptively focus sunlight on a concentrating photovoltaic (CPV) cell sitting on the focus of the Fresnel lens as the sun moves. Because of the unique design, electrowetting tracking allows the concentrator to adaptively track both the daily and seasonal changes of the sun's orbit (dual-axis tracking) without bulky, expensive and inefficient mechanical moving parts. This approach can potentially reduce capital costs for CPV and increases operational efficiency by eliminating the power consumption of mechanical tracking. Importantly, the elimination of bulky tracking hardware and quiet operation will allow extensive residential deployment of concentrated solar power. In comparison with traditional silicon-based photovoltaic (PV) solar cells, the electrowetting-based self-tracking technology will generate ~70% more green energy with a 50% cost reduction.

13/03585 Passive cooling of standalone flat PV module with cotton wick structures

Chandrasekar, M. *et al. Energy Conversion and Management*, 2013, 71, 43–50.
In common, a photovoltaic (PV) module converts only 4–17% of the incoming solar radiation into electricity. Thus, more than 50% of the incident solar energy is converted as heat and the temperature of PV module is increased. The increase in module temperature in turn

decreases the electrical yield and efficiency of the module with a permanent structural damage of the module due to prolonged period of thermal stress (also known as thermal degradation of the module). An effective way of improving efficiency and reducing the rate of thermal degradation of a PV module is to reduce the operating temperature of PV module. This can be achieved by cooling the PV module during operation. Hence in the present work, a simple passive cooling system with cotton wick structures is developed for standalone flat PV modules. The thermal and electrical performance of flat PV module with cooling system consisting of cotton wick structures in combination with water, Al_2O_3/water nanofluid and CuO/water nanofluid are investigated experimentally. The experimental results are also compared with the thermal and electrical performance of flat PV module without cooling system.

13/03586 Performance analysis of a new-design filled-type solar collector with double U-tubes

Liang, R. *et al. Energy and Buildings*, 2013, 57, 220–226.

In order to eliminate the influence of thermal resistance between the absorber tube and the copper fin of the conventional evacuated solar collector, which would decrease the thermal performance of the evacuated tube collector, a filled-typed evacuated tube with single U-tube (SUFET) was presented in a previous work, in which the filled layer was used to transfer energy absorbed by the working fluid flowing in the U-tube. In this paper an improved filled-type evacuated tube with double U-tubes (DUFET) was presented by means of theoretical analysis and experimental study to increase the heat transfer area and then improve the heat transfer efficiency of collectors. The structure of filled-type evacuated tube with double U-tubes was given first, and then the thermal performance of filled-type evacuated tube with double U-tubes was studied in both theory and experiment. The experimental results showed the feasibility and validity of this design. Finally, a comparative study between SUFET and DUFET was given at the same working conditions.

13/03587 Phase change material for enhancing solar water heater, an experimental approach

Fazilati, M. A. and Alemrajabi, A. A. *Energy Conversion and Management*, 2013, 71, 138–145.

In this research, the effects of using phase change materials (PCM) as storage medium on the performance of a solar water heater have been experimentally investigated. A type of paraffin wax is used as PCM in spherical capsules as storage material in the tank of solar water heater. The solar tank is of jacketed shell type. Effect of three solar radiation intensity, i.e. weak, mean and strong are studied. The energy and exergy efficiencies of water heater and the time length the heater can supply hot water have been compared before and after using of PCM in the tank. It is observed that by using PCM in the tank the energy storage density is increased in the tank up to 39% and the exergy efficiency is enhanced up to 16%. Also, it is observed that solar water heater with PCM, can supply hot water with specified temperature at 25% longer time. Improvement in thermal stratification has also been observed by examining temperature histories of different water layers in the tank.

13/03588 Photoelectrochemical cell/dye-sensitized solar cell tandem water splitting systems with transparent and vertically aligned quantum dot sensitized TiO_2 nanorod arrays

Shin, K. *et al. Journal of Power Sources*, 2013, 225, 263–268.

This study reports the fabrication of vertically aligned CdS sensitized TiO_2 nanorod arrays grown on transparent conducting oxide substrate with high transparency as a photoanode in photoelectrochemical cell for water splitting. To realize an unassisted water splitting system, the photoanode and dye-sensitized solar cell tandem structures are tried and their electrochemical behaviours are also investigated. The hydrothermally grown TiO_2 nanorod arrays followed by CdS nanoparticle decoration can improve the light absorption of long wavelength light resulting in increased photocurrent density. Two different techniques (electrodeposition and spray pyrolysis deposition) of CdS nanoparticle sensitization are carried out and their water splitting behaviours in the tandem cell are compared.

13/03589 Rating of roofs' surfaces regarding their solar potential and suitability for PV systems, based on LiDAR data

Lukač, N. *et al. Applied Energy*, 2013, 102, 803–812.

The roof surfaces within urban areas are constantly attracting interest regarding the installation of photovoltaic systems. These systems can improve self-sufficiency of electricity supply, and can help to decrease the emissions of greenhouse gases throughout urban areas. Unfortunately, some roof surfaces are unsuitable for installing photovoltaic systems. This presented work deals with the rating of roof surfaces within urban areas regarding their solar potential and suitability for the installation of photovoltaic systems. The solar potential of a roof's surface is determined by a new method that combines extracted urban topography from LiDAR data with the pyranometer measurements of global and diffuse solar irradiances. Heuristic annual vegetation shadowing and a multi-resolution shadowing model, complete the proposed method. The significance of different influential factors (e.g. shadowing) was analysed extensively. A comparison between the results obtained by the proposed method and measurements performed on an actual PV power plant showed a correlation agreement of 97.4%.

13/03590 Revised feed-in tariff for solar photovoltaic in the United Kingdom: a cloudy future ahead?

Muhammad-Sukki, H. *et al. Energy Policy*, 2013, 52, 832–838.

The UK started implementing a national feed-in tariff (FiT) mechanism on the 1 April 2010, which included specific payment tariffs for solar photovoltaic (PV) installations. However, a revised FiT rate has been put in place starting from 1 April 2012, applicable to any installations with an eligibility date of on or after 3 March 2012. This paper presents, first, an overview of solar PV installation in the UK. This followed by a general concept of the FiT in the UK before analysing the financial impact of the new FiT rate on the consumers. Similar financial analysis is conducted with selected countries in Europe. The financial analysis investigates the total profit, the average rate of return and the payback period. It is found that the new FiT rate generates very low profit, minimum rate of return and a longer payback period, suggesting a downward trend of solar PV uptake in the future.

13/03591 Simulation model linked PV inverter implementation utilizing dSPACE DS1104 controller

Ghani, Z. A. *et al. Energy and Buildings*, 2013, 57, 65–73.

This paper presents the simulation model linked prototype development of a photovoltaic (PV) three-phase inverter utilizing the dSPACE DS1104 controller. The inverter model and control algorithm were developed and simulated in MATLAB/Simulink. The control algorithm of the simulation model is linked to the built inverter prototype by using the dSPACE DS1104 controller board. The control system employs the PI controller to generate the pulse width modulation (PWM) signals for isolated-gate bipolar transistors (IGBTs) switching, thus producing and regulating the 50 Hz sinusoidal ac output voltage. For the input sources, the inverter utilizes 25 units of real PV modules which generate a DC output voltage of 435 V. Simulation results show that the controller managed to regulate the RMS output voltage of 240 V and 100% in magnitude of fundamental component. The test results show that the inverter RMS output voltage and current are stabilized at 240 V and 4.5 A, respectively. The total harmonic distortion of the voltage and current waveform are 2.5% and 3.5% respectively that proved the efficacy of the developed control algorithm.

13/03592 Single-step in-situ preparation of thin film electrolyte for quasi-solid state quantum dot-sensitized solar cells

Wang, S. *et al. Journal of Power Sources*, 2013, 224, 152–157.

Natural polysaccharide Konjac glucomannan (KGM) is, for the first time, applied as the polymer matrix for thin film gel electrolyte in CdS/CdSe quantum dot-sensitized solar cells (QDSCs). The predominance of this thin film quasi-solid state QDSCs lies in the *in situ* preparation of the electrolyte and Cu_2S counter electrode in one step without a mould, which can significantly simplify the cell fabrication process. The cell based on this electrolyte presents an energy conversion efficiency of 4.0% under AM 1.5 illumination of $100\,mW\,cm^{-2}$ with excellent stability compared to that of liquid-based QDSCs.

13/03593 Solar drying for different test conditions: proposed framework for estimation of specific energy consumption and CO_2 emissions mitigation

Singh, S. and Kumar, S. *Energy*, 2013, 51, 27–36.

In this study, drying experiments on mixed-mode solar dryer with cylindrical potato samples have been performed for a wide range of process variables. The variables investigated are absorbed thermal energy, air flow rate, food product loading density and sample thickness. A mathematical framework is developed to estimate several dryer performance indicators namely: drying efficiency, specific energy consumption (SEC), CO_2 emissions mitigation, carbon credits earned and amount of different fossil fuels saved due to use of solar drying. The fossil fuels investigated in the present study are coal, diesel, natural gas and liquefied petroleum gas. The results of investigation indicate that for all drying test conditions, the given dryer is capable to mitigate the maximum CO_2 emissions with the replacement of coal by solar energy. Larger values of absorbed energy and load density cause increased SEC and CO_2 mitigation potential whereas reverse trend is observed for sample thickness. However, the influence of air flow rate on these parameters is found to be quite different. In order to establish functional relationship between SEC and process variables, a correlation is developed using Levenberg–Marquart algorithm. The statistical error analysis reveals that the proposed correlation is capable of satisfactory prediction of experimental results.

13/03594 Solar energy potential atlas for planning energy system off-grid electrification in the Republic of Djibouti

Pillot, B. *et al. Energy Conversion and Management*, 2013, 69, 131–147.

Nowadays, energy supply of rural populations is one of the most important challenges in African developing countries, and more particularly in Sub-Saharan Africa. With only one-third of the population connected to the grid and the high economic and environmental cost of classical energy resources, the use of renewable energies within the rural energy supply pattern is a reliable alternative solution to improve human development of remote populations. Djibouti is a poor small country of Sub-Saharan Africa which perfectly symbolizes this way of life. Electrification rate is only about 30% and the important scattering of rural peoples throughout the country makes grid extension and fuel transportation unsuitable economic solutions to carry energy. The geographically diffused solar resource can therefore be an interesting mean to produce energy where it is consumed. The aim of this study was the creation of the first Djibouti's global horizontal irradiation atlas, including assessment and improvement. To realize this atlas, a satellite-derived irradiance model was used (EUMETSAT O&SI SAF). To validate this model over Djibouti, the authors installed two temporary weather stations during the year 2010 in Djibouti city and Dikhil and compared hourly, daily and monthly irradiation estimates against ground-based measurements. Results showed a good agreement between measures and estimates, with a maximum relative root mean squared error (RRMSE) over the hourly solar atlas of 12.43% and 15.44%, for Dikhil and Djibouti city, respectively. In order to improve geographic information and accuracy of this solar atlas, the authors then disaggregated irradiation maps with a 3 arcsec (∼90 m at the equator) digital elevation model, by taking into consideration terrain-related shading effects and elevation gradient. As current software solutions do not allow downscaling of pre-processed maps, this work was performed by computing a own global model, combination of horizon, elevation correction and irradiance splitting models. The horizon model developed was assessed and compared with other existing models by using a theodolite in mountainous areas of Corsica. Finally, according to the final computed atlas, during the year 2010, mean irradiation all over the country was around 2100 kW h/m^2 and about 82% of the country received over 2000 kW h/m^2. Furthermore, the solar radiation reaching Djibouti corresponded to 20,000 times the total yearly energy consumption of the country in 2005. The retrieved irradiation maps can be used to evaluate relevance of the solar resource over rural areas of the country, and implemented within energy models in order to size stand-alone solar systems.

13/03595 Solar water heating system integrated design in high-rise apartment in China

Shi, J. *et al. Energy and Buildings*, 2013, 58, 19–26.

With the development of urbanization in China, more and more high-rise residential buildings are constructed, mostly with 10–15 storeys. Solar water heating system has been widely used in low-rise residential buildings in China, while its application in high-rise apartment is still in the initial stage. In this paper, the current application situation of solar water heating system in urban residential buildings of China is investigated. Additionally, demonstration projects of high-rise residential building are introduced, in which the application feasibility and limitation of solar water heating system are emphasized and some appropriate planning types of that are discussed. Finally, this paper analyses the applicability of solar water heating systems integrated design in typical high-rise apartments from various aspects (such as architectural elevation, architectural plane and detailed construction) in the planning and designing phase.

13/03596 The design, fabrication and indoor experimental characterisation of an isolated cell photovoltaic module

Paul, D. I. *et al. Solar Energy*, 2013, 88, 1–12.

A significant problem in utilizing the compound parabolic concentrator (CPC) in photovoltaic (PV) applications is the non-uniform illumination on the receiver which results in current reduction for PV modules in which cells are serially connected. A novel PV module with isolated cells, which yield high current for cells located in peak energy fluxes, has been designed and experimentally characterized with and without the CPC using a multi-purpose mobile solar simulator. The CPC had an acceptance half-angle of 30° and truncated geometrical concentration ratio of 1.96. Due to the variation in energy flux profile on each cell, it was found that the energy flux concentration on the surface of the PV module within the CPC varied from 0.9 to 3.6, with high energy flux being concentrated at the edges of the receiver. As a result, the cell performance parameters such as current, short-circuit current, power at maximum power point and fill factor for the cells within the CPC varied depending on the location of the cell in the PV module. The total maximum power output for the cells within the CPC was 25% higher than that without concentration.

13/03597 Thermal energy storage technologies and systems for concentrating solar power plants

Kuravi, S. *et al. Progress in Energy and Combustion Science*, 2013, 39, (4), 285–319.

An overview of thermal energy storage technologies applicable to concentrating solar power plants is presented based on a comprehensive review of the literature. The storage concepts and the state-of-the-art design methodologies used by various researchers are discussed. Though all three basic types of storage media (sensible, latent, thermochemical) have the potential to make solar power plants viable, more research is still needed to improve the thermal performance and economics of these systems. Current research efforts in the area of thermal storage focus on developing new technologies that can reduce the cost from the present levelized cost of energy of thermal storage of 5 cent/kWh to 1 cent/kWh by 2020, with the current trend moving towards higher temperatures. Recent developments are utilizing nano-based technologies and advanced manufacturing methods for achieving this goal. Researchers are emphasizing exergetic efficiencies in the design of storage systems. A combination of different types of storage can be a solution to achieve the required efficiency of power plants at low cost.

13/03598 Tungsten-based oxide semiconductors for solar hydrogen generation

Janáky, C. *et al. Catalysis Today*, 2013, 199, 53–64.

In this focused review the progress achieved in solar water splitting over tungsten based oxide photocatalysts is summarized. Beyond simple doping of WO_3, both binary and ternary oxides are discussed, presenting the various synthesis methods and resulting crystal structures. Theoretical considerations on the band structure are also given including a perspective on possible strategies for band engineering. The effectiveness of such strategies for designing tungsten-based oxide semiconductors as robust photocatalysts for stoichiometric solar water splitting, is reviewed. In addition, progress on Z-scheme based strategies using combined photocatalysts, where WO_3 is responsible for water photooxidation (O_2-evolution) while H_2 generation takes place on its counterpart, is also reviewed.

Wind energy

13/03599 A frequency domain approach to characterize and analyze wind speed patterns

Jung, J. and Tam, K.-S. *Applied Energy*, 2013, 103, 435–443.

This paper introduces the frequency domain approach to characterize and analyse wind speed patterns. It first presents the technique of and the prerequisite conditions for the frequency domain approach. Three years of wind speed data at 10 different locations have been used. This paper demonstrates that wind speed patterns during different times and at different locations can be well characterized by using the frequency domain approach with its compact and structured format. The authors also performed analysis using the characterized dataset. It affirms that the frequency domain approach is a useful indicator for understanding the characteristics of wind speed patterns and can express the information with superior accuracy.

13/03600 Analysis of the control structure of wind energy generation systems based on a permanent magnet synchronous generator

Carranza, O. *et al. Applied Energy*, 2013, 103, 522–538.

This paper presents the analysis of the two usual control structures for variable speed and fixed pitch wind energy generation systems, namely speed and torque control, to determine the most appropriate structure to improve both robustness and reliability of this kind of distributed generators. The study considers all the elements of a typical wind power generation system and it has been carried out in a general way, so that conclusions are independent of the kind of the AC/DC converter that it is used to process the energy at the output of the generator. Particular emphasis was placed on developing a model of the turbine where the mechanical torque is considered as a system variable and not an exogenous disturbance for the system, as in other previous studies. After showing that speed control presents several advantages in terms of stability and reliability, an experimental study of this technique was carried out by using a grid connected wind generation system, which is composed by a three-phase boost rectifier feeding the grid connected inverter. Other practical issues for the design of high efficient wind generation systems, like the use of a Kalman speed estimator to avoid the need of mechanical sensors, are also implemented in the prototype and discussed in the paper.

13/03601 Assessing the economic wind power potential in Austria

Gass, V. *et al. Energy Policy*, 2013, 53, 323–330.

In the European Union, electricity production from wind energy is projected to increase by approximately 16% until 2020. The Austrian energy plan aims at increasing the currently installed wind power capacity from approximately 1 to 3 GW until 2020 including an additional capacity of 700 MW until 2015. The aim of this analysis is to assess economically viable wind turbine sites under current feed-in tariffs considering constraints imposed by infrastructure, the natural environment and ecological preservation zones in Austria. The authors analyse whether the policy target of installing an additional wind power capacity of 700 MW until 2015 is attainable under current legislation and developed a geographical information system-based decision system for wind turbine site selection. Results show that the current feed-in tariff of 9.7 ct $\mathrm{kW\,h^{-1}}$ may trigger an additional installation of 3544 MW. The current feed-in tariff can therefore be considered too high as wind power deployment would exceed the target by far. The results indicate that the targets may be attained more cost-effectively by applying a lower feed-in tariff of 9.1 ct $\mathrm{kW\,h^{-1}}$. Thus, windfall profits at favourable sites and deadweight losses of policy intervention can be minimized while still guaranteeing the deployment of additional wind power capacities.

13/03602 Assessing the state of knowledge of utility-scale wind energy development and operation on non-volant terrestrial and marine wildlife

Lovich, J. E. and Ennen, J. R. *Applied Energy*, 2013, 103, 52–60.

A great deal has been published in the scientific literature regarding the effects of wind energy development and operation on volant (flying) wildlife including birds and bats, although knowledge of how to mitigate negative impacts is still imperfect. The authors reviewed the peer-reviewed scientific literature for information on the known and potential effects of utility-scale wind energy development and operation (USWEDO) on terrestrial and marine non-volant wildlife and found that very little has been published on the topic. Following a similar review for solar energy, the authors identified known and potential effects due to construction and eventual decommissioning of wind energy facilities. Many of the effects are similar and include direct mortality, environmental impacts of destruction and modification of habitat including impacts of roads, and offsite impacts related to construction material acquisition, processing and transportation. Known and potential effects due to operation and maintenance of facilities include habitat fragmentation and barriers to gene flow, as well as effects due to noise, vibration and shadow flicker, electromagnetic field generation, macro- and micro-climate change, predator attraction, and increased fire risk. The scarcity of before-after-control-impact studies hinders the ability to rigorously quantify the effects of USWEDO on non-volant wildlife. The authors conclude that more empirical data are currently needed to fully assess the impact of USWEDO on non-volant wildlife.

13/03603 Assessing the value of wind generation in future carbon constrained electricity industries

Vithayasrichareon, P. and MacGill, I. A. *Energy Policy*, 2013, 53, 400–412.

This paper employs a novel Monte Carlo-based generation portfolio assessment tool to explore the implications of increasing wind penetration and carbon prices within future electricity generation portfolios under considerable uncertainty. This tool combines optimal generation mix techniques with Monte Carlo simulation and portfolio analysis methods to determine expected overall generation costs, associated cost uncertainty and expected CO_2 emissions for different possible generation portfolios. A case study of an electricity industry with coal, combined cycle gas turbines, open cycle gas turbines and wind generation options that faces uncertain future fossil-fuel prices, carbon pricing, electricity demand and plant construction costs is presented to illustrate some of the key issues associated with growing wind penetrations. The case study uses half-hourly demand and wind generation data from South Eastern Australia, and regional estimates of new-build plant costs and characteristics. Results suggest that although wind generation generally increases overall industry costs, it reduces associated cost uncertainties and CO_2 emissions. However, there are some cases in which wind generation can reduce the overall costs of generation portfolios. The extent to which wind penetration affects industry expected costs and uncertainties depends on the level of carbon price and the conventional technology mix in the portfolios.

13/03604 Assessment of wind power predictability as a decision factor in the investment phase of wind farms

Girard, R. *et al. Applied Energy*, 2013, 101, 609–617.

The ability to predict wind power production over the next few hours to days is prerequisites for the secure and economic operation of power systems with high wind power penetration. From the point of view of a producer participating in the day-ahead electricity market, lack of predictability at a wind power production site results in imbalance costs. This paper aims at quantifying the impact on market revenue of, respectively, the predictability and the capacity factor of a wind farm or a cluster of wind farms. This is done through a real-life case study in west Denmark, including wind farm production data and market data. Finally, a prospective analysis is made under the assumption that the imbalance price settlement mechanism will remain the same.

13/03605 China's wind power industry: policy support, technological achievements, and emerging challenges

Wang, Z. *et al. Energy Policy*, 2012, 51, 80–88.

Since 2005 the Chinese wind power technology industry has developed rapidly, with China becoming the largest installer of wind power capacity in the world in 2010. This paper reviews the policy system implemented in China to support the wind power industry, centred on China's 2005 renewable energy law. It examines the industry's achievements over the past two decades, including the development of wind power technology and equipment, the utilization of China's wind power resources, and the cost reductions achieved. It then explores the obstacles affecting the on-going sustainability of the Chinese wind industry, including regulatory barriers, grid integration challenges, and challenges to continued technological innovation. It recommends that integration challenges be addressed through policy reforms, establishing interconnection standards, and creating predictability with forecasting and storage; that market signals be established with long-term development goals and pricing reforms; and that industry limitations be addressed with targeted R&D, improved wind resource assessment and transparency, domestic and international collaborations, and the cultivation of a skilled workforce.

13/03606 Decommissioning wind energy projects: an economic and political analysis

Ferrell, S. L. and DeVuyst, E. A. *Energy Policy*, 2013, 53, 105–113.

Wind energy is the fastest-growing segment of new electrical power capacity in the USA, with the potential for significant growth in the future. To facilitate such growth, a number of concerns between developers and landowners must be resolved, including assurance of wind turbine decommissioning at the end of their useful lives. Oklahoma legislators enlisted the authors to develop an economically sound proposal to ensure developers complete their decommissioning obligations. Economic analysis of turbine decommissioning is complicated by a lack of operational experience, as few US projects have been decommissioned. This leads to a lack of data regarding decommissioning costs. Politically, the negotiation leading to the finally enacted solution juxtaposed economic theory against political pragmatism, leading to a different but hopefully sound solution. This article will provide background for the decommissioning issue, chronicle the development of the decommissioning component of the Oklahoma Wind Energy Act, and frame issues that remain for policymakers in regulating wind power development.

13/03607 Differences between along-wind and cross-wind solar irradiance variability on small spatial scales

Hinkelman, L. M. *Solar Energy*, 2013, 88, 192–203.

This study investigates the relationship between the downwelling solar irradiances measured at pairs of stations in a unique dense radiometer array on Oahu Island. The nearly constant wind direction at this site allows us to examine irradiance variability in the along-wind and cross-wind directions separately. Over 13 days dominated by broken clouds, the correlation between the ramp time series from radiometer pairs is found to depend on the separation and relative orientation of the stations as well as the time interval over which the ramps are computed. In general, correlations are highest over short distances and increase with the averaging time. The degree of smoothing achieved by combining the ramps from a pair of stations depends on the correlation of their ramp time series, which in turn depends on their separation and the orientation of the axis between them. For 60-s ramps, correlation drops more rapidly with distance for along-wind station pairs than for cross-wind pairs, so that greater smoothing is achieved for stations oriented in the along-wind direction. A mechanism for this alignment-dependent behaviour is proposed and supported by additional analysis. The results of this study highlight the importance of accounting for local meteorological conditions when designing individual or distributed photovoltaic systems.

13/03608 Direct model reference adaptive internal model controller for better voltage sag ride through in doubly fed induction generator wind farms

Amuthan, N. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 255–263.

This paper presents the function of a direct model reference adaptive internal model controller (DMRAIMC) with variable gain adjustment mechanism for a doubly fed induction generator (DFIG) in a wind farm. Rotor current is controlled using the above controller with variable gain adjustment mechanism achieved using fuzzy sets and ANFIS to improve the voltage sag ride. Performance of the variable gain and linearly variable gain adjustment mechanisms are compared and their improvements are explored. Simulation results are used to demonstrate the effectiveness and robustness of the proposed control strategy, during variations in the variable gain adjustment mechanism.

13/03609 Dynamic maximum available power of fixed-speed wind turbine at islanding operation

Najafi, H. R. and Dastyar, F. *International Journal of Electrical Power & Energy Systems*, 2013, 47, 147–156.

Increasing of wind power penetration at power systems requires the development of adequate wind turbine models and consequently useful indexes. Among different models, dynamic model has an important role as a fundamental part of wind farms for representing the dynamic behaviour of wind farms at different operating conditions. In this paper, a suitable dynamic model is introduced for wind farms with fixed speed wind turbines. This model is proposed by aggregating the individual wind turbines into an equivalent wind turbine model that operates on an equivalent wind farm electric network. Thus, the system under study is modelled by a set of dynamic and algebraic equations. Based on proposed dynamic model a useful novel index is introduced for calculation of the injection power ability of the wind farm that is an urgent issue in the planning and operating of wind farms. This index is named dynamic maximum available power (DMAP). In addition, sensitivity analysis of DMAP with respect to effective parameters is carried out and the results are shown.

13/03610 Planning for distributed wind generation under active management mode

Zhang, J. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 140–146.

In the smart grid (SG), the active management (AM) mode will be applied for the connection and operation of distributed generation (DG), which means real time control and management of DG units and distribution network devices based on real time measurements of primary system parameters. In this paper, a novel bi-level programming model for distributed wind generation (DWG) planning under AM mode is put forward. The model takes the maximum expectation of net benefit of DWG as the upper level program objective, and takes the minimum expectation of generation curtailment as the lower level program objective. The impact of active management algorithm on improvement of branch power flow and node voltage is taken into account. A hybrid algorithm combining the plant growth simulation algorithm (PGSA) with probabilistic optimal power flow (POPF) algorithm is presented to solve the optimal planning of DWG under AM mode. The case studies have been carried out on a 33-node distribution network, and the results verify the rationality of the planning model and the effectiveness of the proposed method.

13/03611 Quantifying the health and environmental benefits of wind power to natural gas

McCubbin, D. and Sovacool, B. K. *Energy Policy*, 2013, 53, 429–441.

How tangible are the costs of natural gas compared to the benefits of one of the fastest growing sources of electricity – wind energy – in the USA? To answer this question, this paper calculates the benefits of wind energy derived from two locations: the 580 MW wind farm at Altamont Pass, California, and the 22 MW wind farm in Sawtooth, Idaho. Both wind farms have environmental and economic benefits that should be considered when evaluating the comparative costs of natural gas and wind energy. Though there are uncertainties within the data collected, for the period 2012–2031, the turbines at Altamont Pass will likely avoid anywhere from $560 million to $4.38 billion in human health and climate related externalities, and the turbines at Sawtooth will likely avoid $18 million to $104 million of human health and climate-related externalities. Translating these negative externalities into a cost per kWh of electricity, it is estimated that Altamont will avoid costs of 1.8–11.8 cents/kWh and Sawtooth will avoid costs of 1.5–8.2 cents/kWh.

13/03612 Review of wind power tariff policies in China

Hu, Z. *et al. Energy Policy*, 2013, 53, 41–50.

In the past 20 years, China has paid significant attention to wind power. Onshore wind power in China has experienced tremendous growth since 2005, and offshore wind power development has been on-going since 2009. In 2010, with a total installed wind power capacity of 41.8 GW, China surpassed the USA as the country with the biggest wind power capacity in the world. By comparing the wind power situations of three typical countries, Germany, Spain, and Denmark, this paper provides a comprehensive evaluation and insights into the prospects of China's wind power development. The analysis is carried out in four aspects including technology, wind resources, administration and time/space frame. It was concluded that both German and Spanish have been growing rapidly in onshore capacity since policy improvements were made. In Denmark, large financial subsidies flow to foreign markets with power exports, creating inverse cost-benefit ratios. Incentives are in place for German and Danish offshore wind power, while China will have to remove institutional barriers to enable a leap in wind power development. In China, cross-subsidies are provided from thermal power (coal-fired power generation) in order to limit thermal power while encouraging wind power. However, the mass installation of wind power capacity completely relies on power subsidies. Furthermore, this study illustrates that capacity growth should not be the only consideration for wind power development. It is more important to do a comprehensive evaluation of multi-sectorial efforts in order to achieve long-term development.

13/03613 Scenario-based dynamic economic emission dispatch considering load and wind power uncertainties

Aghaei, J. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 351–367.

This study protracts the multi-objective dynamic economic emission dispatch (DEED) problem by integrating wind power output of wind turbines. DEED simultaneously minimizes total electrical energy costs and emissions over a 24-h time span. In order to model the random nature of load demand and wind forecast errors, a scenario-based stochastic programming framework is presented. A scenario set is generated by a roulette wheel mechanism based on the probability distribution functions of these input uncertain variables. Therewith, the stochastic DEED (SDEED) problem is transformed into an equivalent deterministic scenario-based DEED. Thus, to solve the complicated non-linear, non-smooth, and non-differentiable SDEED, an enhanced particle swarm optimization (PSO) algorithm is applied to obtain the best solution for the corresponding scenarios. In order to improve the quality of the solutions attained by PSO a self-adaptive probabilistic mutation strategy is used to escape from local minima. The proposed framework is successfully applied to four test systems with small, medium, and large-scale characteristics. In this regard, some metrics are used in order to characterize the effective performance of the solution method.

13/03614 Shifting towards offshore wind energy – recent activity and future development

Kaldellis, J. K. and Kapsali, M. *Energy Policy*, 2013, 53, 136–148.

To date, most of the existing wind farms have been built on-land but during the last few years many countries have also invested in offshore applications. The shift towards offshore wind project developments has mainly been driven by European energy policies, especially in north-west countries. In offshore sites the winds are stronger and steadier than on-land, making wind farms more productive with higher capacity factors. On the other hand, although offshore wind energy is not in its infancy period, most of the costs associated with its development are still much higher from onshore counterparts; however some recent technological progress may have the potential to narrow this gap in the years to come. In the present work, an overview of the activity noted in the field of offshore wind energy is carried out, with emphasis being given on the current status and future trends of the technology employed, examining at the same time energy production and availability issues as well as economic considerations.

13/03615 Short-term strategies for Dutch wind power producers to reduce imbalance costs

Chaves-Ávila, J. P. *et al. Energy Policy*, 2013, 52, 573–582.

The paper assesses bidding strategies for a wind power producer in the Netherlands. To this end, a three-stage stochastic optimization framework is used, maximizing wind power producer's profit using the day-ahead and cross-border intraday market, taking into account available interconnection capacity. Results show that the wind power producer can increase its profits by trading on the intraday market and – under certain imbalance prices – by intentionally creating imbalances. Uncertainties about prices, power forecast and interconnection capacity at the day-ahead and intraday timeframes have also been considered.

13/03616 Technical characteristic analysis of wind energy conversion systems for sustainable development

BoroumandJazi, G. *et al. Energy Conversion and Management*, 2013, 69, 87–94.

Wind energy as a clean, environmentally friendly and cost effective renewable energy resource, is taken into consideration by many developed and developing countries as a promising means to provide electrical energy. In feasibility study stage of the wind energy systems, the sustainability analysis is one of the main issues that can assure the investors and stockholders to invest in this renewable energy. Since a system can be truly sustainable by achieving the energetic, ecological and economic sustainability, this study will focus on the technical characteristics and performance analysis of the wind energy systems.

The relations between reliability, availability, energy and exergy efficiency, risk management and the environmental impact of the wind energy systems are investigated in the context of this study. It is concluded that the wind characteristics data and the wind speed are the main effective parameters on its reliability and availability. It is also revealed that considering the system loss, exergy efficiency results of the wind energy systems are more reliable than the energy efficiencies. In order to avoid future failure of the systems, the causes of the failure are investigated and it was concluded that the structural failures caused by storms and strong winds are known as the most prevalent failures.

13/03617 Two fuzzy-based direct power control strategies for doubly-fed induction generators in wind energy conversion systems

Pichan, M. *et al. Energy*, 2013, 51, 154–162.

This paper proposes two novel direct power control (DPC) strategies for a doubly fed induction generator (DFIG)-based wind energy conversion system based on a fuzzy logic controller (FLC). At first, the mathematical model of the DFIG in the synchronous reference frame is derived. Then, based on this model, two novel FLC-based DPC strategies, called fuzzy-based DPC (FDPC) and fully fuzzy-based DPC (FFDPC) are proposed. In the FDPC, the required rotor voltages to eliminate power errors within each fixed sampling period are directly calculated based on the FLC, the measured active and reactive powers, the stator voltage and some machine parameters. On the other hand, in the FFDPC, the rotor voltages are directly calculated from the FLC. The control structures of proposed methods are very simple. Compared to the conventional switching table-based DPC, in the proposed methods, the hysteresis comparator and the switching table are replaced by a simple FLC and a pulse width modulation modulator. The converter switching frequency is constant which simplifies the practical implementation. Also the proposed methods are robust against machine parameters mismatches and grid voltage disturbances. Extensive simulations in Matlab/Simulink are performed to confirm the effectiveness of the proposed methods under transient and steady state conditions.

13/03618 Wind farm layout optimization using genetic algorithm with different hub height wind turbines

Chen, Y. *et al. Energy Conversion and Management*, 2013, 70, 56–65.

Layout optimization is one of the methods to increase wind farm's utilization rate and power output. Previous researches have revealed that different hub height wind turbines may increase wind farm's power output. However, few researches focus on optimizing a wind farm's layout in a two-dimensional area using different hub height wind turbines. In this paper, the authors first investigate the effect of using different hub height wind turbines in a small wind farm on power output. Three different wind conditions are analysed using nested genetic algorithm, where the results show that power output of the wind farm using different hub height wind turbines will be increased even when the total numbers of wind turbines are same. Different cost models are also taken into account in the analysis, and results show that different hub height wind turbines can also improve cost per unit power of a wind farm. At last, a large wind farm with commercial wind turbines is analysed to further examine the benefits of using different hub height wind turbines in more realistic conditions.

Others, including economics

13/03619 A future role for cascade hydropower in the electricity system of China

Tang, X. and Zhou, J. *Energy Policy*, 2012, 51, 358–363.

Due to the dominance of coal power, the electricity sector is the primary contributor of greenhouse gas emissions in China. The increase of peak-load and intermittent renewable power requires significant resources of regulation facilities. Comprehensively utilizing large-scale cascade hydropower plants (CHPPs), which are being rapidly developed in China, as renewable regulating facilities would be a strategic decision, considering the flexibility of hydropower. Jointly modelling a set of CHPP in the upstream Yangtze River indicated that the CHPP can regulate peak-load up to 30–40 GW and intermittent renewables to scales of nearly 15 GW from wind and solar sources with the help of ±800 KV ultra-high voltage direct current (UHVDC) transmissions. The present study shows that the hydraulic stability of the concerned river reaches can be preserved easily and the comprehensive efficiency of regulation and transmission by CHPPs is much higher than that of pumped hydro-energy storage stations. As increasingly more giant CHPPs emerge in west China, using them primarily as regulating facilities can enhance the structure of power grids, promote the development of renewables, save energy and reduce emissions. Thus the authors propose to shift the CHPPs that were originally projected mainly for electricity to facility primarily for power improvement.

13/03620 A multi-criteria methodology for energy planning and developing renewable energy sources at a regional level: a case study Thassos, Greece

Mourmouris, J. C. and Potolias, C. *Energy Policy*, 2013, 52, 522–530.

Rational energy planning under the pressure of environmental and economic problems is imperative to humanity. An evaluational framework is proposed in order to support energy planning for promoting the use of renewable energy sources. A multi-criteria decision analysis is adopted, detailing exploitation of renewable energy sources (including wind, solar, biomass, geothermal, and small hydro) for power and heat generation. The aim of this paper is the analysis and development of a multilevel decision-making structure, utilizing multiple criteria for energy planning and exploitation of renewable energy sources at the regional level. The proposed evaluation framework focuses on the use of a multi-criteria approach as a tool for supporting energy planning in the area of concern, based on a pool of qualitative and quantitative evaluation criteria. The final aim of this study is to discover the optimal amount of each renewable energy source that can be produced in the region and to contribute to an optimal energy mix. In this paper, a case study for the island of Thassos, Greece is analysed. The results prove that renewable energy source exploitation at a regional level can satisfy increasing power demands through environmental friendly energy systems that combine wind power, biomass and photovoltaic systems.

13/03621 Assessment of wave energy resource of the Black Sea based on 15-year numerical hindcast data

Akpinar, A. and Kömürcü, M. İ. *Applied Energy*, 2013, 101, 502–512.

In this study, the existence and variability of wave energy resource potential of the Black Sea based on 15-year hindcast data is described in detail. The hindcasts of wave parameters were carried out by using the third generation wave prediction model (Simulated WAves Nearshore – SWAN), which is one of the most popular numerical wave models and has been widely used for estimating ocean waves. The model was forced with the ECMWF ERA interim wind fields and applied with a spatial resolution of about $0.0167^\circ \times 0.0167^\circ$ and a model time step of 6 h to resolve efficiently offshore and nearshore wave conditions. The results were presented in the form of charts of the spatial distribution of significant wave height and wave power, on a monthly, seasonal and annual basis. Annual energy was calculated in the study region with the hindcast data set covering 15 years (1995–2009). The areas with the highest wave energy resource were determined and the south west coasts of the Black Sea are suggested as the best site for the installation of a wave farm. It was determined the western parts of the Black Sea (especially the south-west) are exposed to energetic waves more than the eastern parts.

13/03622 Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time

Budischak, C. *et al. Journal of Power Sources*, 2013, 225, 60–74.

This study models many combinations of renewable electricity sources (inland wind, offshore wind, and photovoltaics) with electrochemical storage (batteries and fuel cells), incorporated into a large grid system (72 GW). The purpose is twofold: (1) although a single renewable generator at one site produces intermittent power, combinations of diverse renewables at diverse sites are sought, with storage, that are not intermittent and satisfy need a given fraction of hours; (2) minimal cost is sought, calculating true cost of electricity without subsidies and with inclusion of external costs. The model evaluated over 28 billion combinations of renewables and storage, each tested over 35,040 h (4 years) of load and weather data. It was found that the least cost solutions yield seemingly excessive generation capacity – at times, almost three times the electricity needed to meet electrical load. This is because diverse renewable generation and the excess capacity together meet electric load with less storage, lowering total system cost. At 2030 technology costs and with excess electricity displacing natural gas, it was found that the electric system can be powered 90%–99.9% of hours entirely on renewable electricity, at costs comparable to today's – but only with the optimization of the mix of generation and storage technologies.

13/03623 Domestic hot water consumption estimates for solar thermal system sizing

Evarts, J. C. and Swan, L. G. *Energy and Buildings*, 2013, 58, 58–65.

Accurate domestic hot water (DHW) consumption information is useful for solar-thermal-hot-water-system designers and policy makers supporting solar-thermal-incentive programs. Conducting field studies of DHW-consumption patterns is difficult and costly, and as a result, there are few studies available in the body of literature. Several DHW models exist, however these aggregate models are often dated and most fail to identify the influence of the number of occupants in the dwelling, instead relying on a standard-per-capita consumption. The standard of 60 litres/capita/day (lcd) is found to be accurate for households of four or more occupants, but significantly under estimates per-capita-hot-water consumption for households with three or fewer occupants, consequently, under estimating the energy and greenhouse gas emissions savings of solar-DHW programmes. The new estimate presented here addresses these issues. This study was conducted using utility-billing data, and occupant responses from a survey of 1594 residences. The data includes annual total-water use, energy consumption, costs, and basic information about the residence and occupants. The method isolates average-oil used in water heaters and then estimates system performance to calculate the volume of hot water heated. The findings include total-water use, oil consumption for water heating, and DHW use based on occupancy for households of one through six occupants.

13/03624 Dynamic analysis of hybrid energy systems under flexible operation and variable renewable generation – part I: dynamic performance analysis

Garcia, H. E. *et al. Energy*, 2013, 52, 1–16.

Dynamic analysis of hybrid energy systems (HES) under flexible operation and variable renewable generation is considered in this two-part communication to better understand various challenges and opportunities associated with the high variability arising from integrating renewable energy into the power grid. Unique consequences are addressed by devising advanced HES solutions in which multiple forms of energy commodities, such as electricity and chemical products, may be exchanged. Dynamic models of various unit operations are developed and integrated within two different HES options. One HES option, termed traditional, produces electricity only and consists of a primary heat generator, a steam turbine generator, a wind farm, and a battery storage. The other HES option, termed advanced, includes not only the components present in the traditional option but also a chemical plant complex to repurpose excess energy for non-electricity services, such as for the production of chemical goods. In either case, a given HES is connected to the power grid at a point of common coupling and requested to deliver a certain electricity generation profile as dictated by a regional power grid operator based on a predicted demand curve. A dynamic performance analysis of these highly coupled HES is conducted in this part one of the communication to identify their key dynamical properties and limitations and to prescribe solutions for best managing and mitigating the high variability introduced from incorporating renewable energy into the energy mix.

13/03625 Dynamic analysis of hybrid energy systems under flexible operation and variable renewable generation – part II: dynamic cost analysis

Garcia, H. E. *et al. Energy*, 2013, 52, 17–26.

Dynamic analysis of hybrid energy systems (HES) under flexible operation and variable renewable generation is considered in this two-part communication to better understand various challenges and opportunities associated with the high system variability arising from the integration of renewable energy into the power grid. Advanced HES solutions are investigated in which multiple forms of energy commodities, such as electricity and chemical products, may be exchanged. In particular, a comparative dynamic cost analysis is conducted in this part two of the communication to determine best HES options. The cost function includes a set of metrics for computing fixed costs, such as fixed operations and maintenance and overnight capital costs, and also variable operational costs, such as cost of operational variability, variable operations and maintenance cost, and cost of environmental impact, together with revenues. Assuming natural gas, coal and nuclear as primary heat sources, preliminary results identify the level of renewable penetration at which a given advanced HES option (e.g. a nuclear hybrid) becomes increasingly more economical than a traditional electricity-only generation solution. Conditions are also revealed under which carbon resources may be better utilized as carbon sources for chemical production rather than as combustion material for electricity generation.

13/03626 Facilitating the financing of bioenergy projects in sub-Saharan Africa

Hofmann, M. and Khatun, K. *Energy Policy*, 2013, 52, 373–384.

The purpose of this paper is to identify and develop potential solutions on how to facilitate the financing of bioenergy projects in Sub-Saharan Africa. The authors focus on four main areas that have been identified from empirical research in achieving this objective; these are: (i) financing, (ii) markets, (iii) trade and (iv) policy. The sources utilized consist of primary and secondary data compilation and analysis. Of particular relevance are the results of a market survey undertaken on funding opportunities, where the perspectives of both, project developers as well as project financiers are taken into account. Results indicate that the four areas cannot be treated autonomously, as they not only overlap but impact each other. There are a number of difficulties for biofuel ventures, not least the nature of the projects themselves, but also around the financing and political landscape of these enterprises. Common solutions which cross cut the four areas are the need to raise awareness and the skillsets, in areas including, financing opportunities, markets, policy, technical aspects among a range of stakeholders involved in biofuel ventures. There is also a necessity to create a supporting framework for the emerging carbon trading-related activities in Africa.

13/03627 Framework for the implementation of a new renewable energy system in an educational facility

Hong, T. *et al. Applied Energy*, 2013, 103, 539–551.

New renewable energy (NRE) has attracted considerable attention as a future energy source that might be a significant factor in establishing a sustainable energy supply system. This issue is becoming increasingly important due to the instability of oil prices and the issues surrounding climate change. The purpose of this research is to develop a framework for the implementation of building-scale NRE systems (solar photovoltaic, solar thermal, geothermal, and wind energy systems). For this research, 'C' High School facility in Seoul was selected as a case study, from where project characteristics and energy consumption data in 2010 were collected. This research (i) collected facility usage information and carried out market research on NRE systems; (ii) conducted a feasibility study of NRE systems; (iii) designed a detailed NRE system through energy simulation by using the software program 'RETScreen'; and (iv) selected the optimal NRE system through a life cycle cost analysis and life cycle CO_2 analysis. This research can be useful for educational facility managers or policy-makers to determine whether or not an NRE system need to be introduced in a preliminary feasibility study, and to find out which NRE system is the optimal one for a given facility in the detailed design process. Also, it would benefit contractors in a competitive bidding process, where as one of the CO_2 emission reduction methods, the results of this research could be a part of an educational facility improvement program.

13/03628 GIS-based site selection methodology for hybrid renewable energy systems: a case study from western Turkey

Aydin, N. Y. *et al. Energy Conversion and Management*, 2013, 70, 90–106.

A disadvantage of renewable energy systems is that continuous energy generation is not possible by using only one type of renewable energy system, since renewable energy resources depend on climate and weather conditions. Two or more renewable energy systems can be integrated into a hybrid system to overcome this problem so that when one resource is not available, the other can continue producing energy. Another disadvantage of renewable energy sources is that they are not available at every geographic location. Their use is mostly advantageous at remote locations that often are of high ecological value. Thus, identification of preferable locations for renewable energy systems is a decision-making problem that requires evaluation of the potential of the resource together with economic and environmental limitations. This paper introduces a methodology for site selection of hybrid wind solar–photovoltaic renewable energy systems. First, environmental acceptability and economic feasibility objectives are identified through a comprehensive review of the literature, current Turkish laws and legislations, and interviews with the General Directorate of Electrical Power Resources Survey and Development Administration of Turkey. Second, viable locations in terms of environmental acceptability and economic feasibility are determined through a fuzzy decision-making procedure that uses ordered weighted averaging algorithm for aggregating multiple objectives. Then, priority sites are identified separately for wind and solar energy systems by using geographic information system (GIS) and finally associated maps are overlaid to obtain the most feasible locations for hybrid wind solar–photovoltaic systems.

13/03629 Impact of perennial energy crops income variability on the crop selection of risk averse farmers

Alexander, P. and Moran, D. *Energy Policy*, 2013, 52, 587–596.

The UK government's policy is for the area of perennial energy crops in the UK to expand significantly. Farmers need to choose these crops in preference to conventional rotations for this to be achievable. This paper looks at the potential level and variability of perennial energy crop incomes and the relation to incomes from conventional arable crops. Assuming energy crop prices are correlated to oil prices the results suggests that incomes from them are not well correlated to conventional arable crop incomes. A farm scale mathematical programming model is then used to attempt to understand the effect on risk-averse farmers crop selection. The inclusion of risk reduces the energy crop price required for the selection of these crops. However yields towards the highest of those predicted in the UK are still required to make them an optimal choice, suggesting only a small area of energy crops within the UK would be expected to be chosen to be grown. This must be regarded as a tentative conclusion, primarily due to high sensitivity found to crop yields, resulting in the proposal for further work to apply the model using spatially disaggregated data.

13/03630 Numerical modeling of a wave energy converter based on U-shaped interior oscillating water column

Fonseca, N. and Pessoa, J. *Applied Ocean Research*, 2013, 40, 60–73.

The paper presents a concept of a wave energy converter and the numerical model to calculate the hydrodynamic responses in waves and the power produced by the power take off system. The system consists of an asymmetric floater with an interior U-tank partially filled with water and two lateral air chambers connected by a duct. The motion of the U-shaped oscillating water column, mainly induced by the rolling of the floater, forces the air through the duct where a Wells turbine is installed to absorb the wave energy. The wave-floater hydrodynamics is calculated with a Green's function panel method, while the oscillating water column motions hydro-mechanics are derived from the one-dimensional Euler's equation. The dynamics of the Wells turbine is realistically represented by one additional differential equation on the unknown air pressure fluctuation. This equation is derived assuming small amplitude motions of the water column and assuming the linear isentropic relation is valid for the air thermodynamics in the air chambers. The Wells turbine is characterized by a drastic drop of efficiency above a critical pressure value due to stalling on the blades. The effect of a by-pass valve to prevent stalling is introduced in the numerical model in a simplistic way. The numerical model is implemented and tested for a wave energy converter with a displacement of 1150 t, including 490 t for the interior water column, and an installed turbine with 2.3 m of diameter. An analysis of the influence of changing different design parameters on the system efficiency is also presented.

13/03631 Performance assessment of tidal stream turbines: a parametric approach

Ramos, V. and Iglesias, G. *Energy Conversion and Management*, 2013, 69, 49–57.

Due to the high cost of a tidal stream plant it is essential to select turbines that will have an optimum performance at the site in question. The objective of this work is twofold: (i) to present a procedure to compare the performance of different tidal stream turbines (TSTs) at a given site, and (ii) to illustrate it by means of a case study. A new parameter, the site-specific turbine efficiency, is defined ad hoc and used alongside the availability and capacity factors, and the energy output over a reference period of time. These four performance parameters are determined for each turbine on the basis of the characteristics of the flow at the site. The procedure is illustrated with a case study in which two TSTs, the Gorlov helicoidal turbine and the Evopod, are compared for a site in an estuary. It is found that the availability and capacity factors of the Gorlov machine are higher (implying more operation hours and equivalent hours per annum) but the Evopod has larger site-specific efficiency and total energy output. In conclusion, a parametric approach that allows to compare the performance of different TSTs at any site of interest is presented and illustrated with a case study.

13/03632 Potential of genetically modified oilseed rape for biofuels in Austria: land use patterns and coexistence constraints could decrease domestic feedstock production

Moser, D. *et al. Biomass and Bioenergy*, 2013, 50, 35–44.

Like other European Union (EU) member states, Austria will meet the substitution target of the EU European Renewable Energy Directive for transportation almost exclusively by first generation biofuels, primarily biodiesel from oilseed rape (OSR). Genetically modified (GM) plants have been promoted as a new option for biofuel production as they promise higher yield or higher quality feedstock. The authors tested implications of a GM OSR application for biodiesel production in Austria by means of high resolution spatially explicit simulation of 140 different coexistence scenarios within six main OSR cropping regions in Austria (2400 km^2). They identified structural land use characteristics such as field size, land use diversity, land holding patterns and the proportion of the target crop as the predominant factors which influence overall production of OSR in a coexistence scenario. Assuming isolation distances of 800 m and non-GM-OSR proportions of at least 10% resulted in a loss of area for cultivation of OSR in all study areas ranging from −4.5% to more than −25%, depending on the percentage of GM farmers and on the region. The authors could show that particularly the current primary OSR cropping regions are largely unsuitable for coexistence and would suffer from a net loss of OSR area even at isolation distances of 400 or 800 m. Coexistence constraints associated with application of GM OSR are likely to offset possible GM gains by substantially reducing farmland for OSR cultivation, thus contradicting the political aim to increase domestic OSR area to meet the combined demands of food, feed and biofuel production.

13/03633 Power quality analysis for building integrated PV and micro wind turbine in New Zealand

Nair, N.-K. C. and Jing, L. *Energy and Buildings*, 2013, 58, 302–309.

Many of the existing small-scale renewable generation technologies rely on electronic inverter switching 0010, 0015 and 0020 at the integration point. Currently, due to the switching characteristics of inverters, power quality could become a problem for end users and also impact on regulatory limits for distribution line utilities. The existing inverter technology application of micro wind turbine and solar photovoltaic cells is being currently deployed and assessed several distribution network utilities like Vector in New Zealand. In this paper the outcome of these trials are analysed in addition to proposing the modelling framework to quantify the power quality effect of small-scale renewable generation cells. A practical and comprehensive way to assess the power quality impacts due to large-scale integration of these new renewable generation devices is also presented. Software such as ATP-EMTP and DIgSILENT PowerFactory is used in this work to provide the platforms for assessment of an individual device and overall network effect, respectively.

13/03634 Renewable energy policies in Europe: converging or diverging?

Kitzing, L. *et al. Energy Policy*, 2012, 51, 192–201.

Nations today are urgently challenged with achieving a significant increase in the deployment of renewable energies. In Europe that need has given rise to a debate about the most effective and efficient support strategy. Whilst the different interests debate whether full European harmonization or strengthening of national support policies for electricity from renewable energy sources (RES-E) is the best way forward, individual national support schemes are rapidly evolving. This study investigates how the EU member states have applied support policy types over the last decade. By identifying predominant developments in the application of feed-in tariffs, premiums, tradable green certificates, tax incentives, investment grants, and financing support for specific technologies (wind, biomass, PV), this study shows that Europe is currently experiencing certain tendencies towards a 'bottom-up' convergence of how national policy-makers design RES-E policy supports. While some outliers remain, the policy supports of most countries become more similar in the policy types applied (dominance of feed-in tariffs) and in their scope of implementation (differentiation for installation sizes and 'stacking' of multiple instruments). These trends in national decision-making, which show tendencies of convergence, could make an EU-driven 'top-down' harmonization of support either dispensable or at least (depending on the agreement) less controversial.

13/03635 Short term hydrothermal scheduling using multi-objective differential evolution with three chaotic sequences

Zhang, H. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 85–99.

Short-term hydrothermal optimal scheduling with economic emission (SHOSEE) is a multi-objective and complex constrained optimization problem. In this paper, three chaotic sequences based multi-objective differential evolution (CS-MODE) is proposed to solve this SHOSEE problem, and it utilizes elitist archive mechanism to retain the non-dominated individuals, which improves the convergence ability in the differential evolution, and a heuristic two-step constraint-handling technique is utilized to handle those complex equality and inequality constraints in SHOSEE problem. Furthermore, in order to avoid premature convergence, the proposed CS-MODEs have integrated three chaotic mappings into differential evolution to implement population space search, it enlarges search space and enriches the diversity of individuals generated in evolution process. The compromise scheme is selected from the non-dominated set to represent the average efficiency level on the hydrothermal system, and the obtained simulation result also reveals the feasibility and effectiveness of proposed CS-MODEs in comparison to other methods established recently.

13/03636 Solar and pellet combisystem for apartment buildings: heat losses and efficiency improvements of the pellet boiler

Žandeckis, A. *et al. Applied Energy*, 2013, 101, 244–252.

This paper is based on the analysis of the solar combisystem installed in a four-storey apartment building in Sigulda, Latvia. The combisystem consists of: 42 m^2 of flat plate solar collectors, a 2.35 m^3 accumulation tank and a 100 kW pellet boiler as the auxiliary heater. This paper focuses on the optimization of the thermal performance of the pellet boiler. During laboratory tests on the 25 kW pellet boiler, the influence of the supply ratio of the combustion air, the chemical and heat losses in the flue gases on the performance of the boiler was established. The results demonstrate the optimum thermal performance, CO emissions, chemical and heat losses, which are related to the amount of free oxygen in the flue gases. The results of the laboratory tests were then applied to optimize the operation of the 100 kW pellet boiler. The flue gas measurements for the 100 kW boiler were performed in order to identify the O_2 concentration, CO emissions and flue gas temperature. The results showed that what is required to optimize performance is to reduce the amount of air supplied to the boiler's combustion chamber. Changes were made to the boiler's control algorithms to achieve the desired result. Additionally, boiler performance was improved by changing the location of the air intake point. Decreasing temperatures in the heat accumulation tank were achieved by making modifications to the boiler's control algorithms.

13/03637 Solar balloons as mixed solar–wind power systems

Grena, R. *Solar Energy*, 2013, 88, 215–226.

Solar balloons, in which solar radiation is used to heat directly the air in a hot-air flying balloon, can be used as a mixed power system that exploits both solar radiation and high-altitude winds. If the balloon is heated at ground level and then released, the upward drift due to solar energy and the lateral drift due to wind can both be used to generate energy. At high altitude, the balloon is completely deflated (except for a small Helium-filled chamber, which prevents the balloon from falling) and pulled to the ground: the aerodynamical drag is now strongly reduced with respect to the ascent. A production cycle is simulated for balloons of different sizes and in different working conditions, assessing the feasibility of such a system, calculating the energy output and the solar/wind proportion of the produced energy. Simulation results show that such a system can produce energy with non-negligible solar-to-electricity efficiency (up to 5%). Moreover, while this is primarily a solar-based system, wind can yield a significant amount of additional energy for wind velocities greater than 15 m/s.

13/03638 Stochastic production planning for a biofuel supply chain under demand and price uncertainties

Awudu, I. and Zhang, J. *Applied Energy*, 2013, 103, 189–196.

This study proposes a stochastic production planning model for a biofuel supply chain under demand and price uncertainties. The supply chain consists of biomass suppliers, biofuel refinery plants and distribution centres. A stochastic linear programming model is proposed within a single-period planning framework to maximize the expected profit. Decisions such as the amount of raw materials purchased, the amount of raw materials consumed and the amount of products produced are considered. Demands of end products are uncertain with known probability distributions. The prices of end products follow geometric Brownian motion. Benders' decomposition with Monte Carlo simulation technique is applied to solve the proposed model. To demonstrate the effectiveness of the proposed stochastic model and the decomposition algorithm, a representative supply chain for an ethanol plant in North Dakota is considered. To investigate the results of the proposed model, a simulation framework is developed to compare the performances of deterministic model and proposed stochastic model. The results from the simulation indicate the proposed model obtain higher expected profit than the deterministic model under different uncertainty settings. Sensitivity analyses are performed to gain management insight on how profit changes due to the uncertainties affect the model developed.

13/03639 The market value of variable renewables: the effect of solar wind power variability on their relative price

Hirth, L. *Energy Economics*, 2013, 38, 218–236.

This paper provides a comprehensive discussion of the market value of variable renewable energy (VRE). The inherent variability of wind speeds and solar radiation affects the price that VRE generators receive on the market (market value). During windy and sunny times the additional electricity supply reduces the prices. Because the drop is larger with more installed capacity, the market value of VRE falls with higher penetration rate. This study aims to develop a better understanding on how the market value with penetration, and how policies and prices affect the market value. Quantitative evidence is derived from a review of published studies, regression analysis of market data, and the calibrated model of the European electricity market EMMA. The value of wind power was found to fall from 110% of the average power price to 50–80% as wind penetration increases from zero to 30% of total electricity consumption. For solar power, similarly low value levels are reached already at 15% penetration. Hence, competitive large-scale renewable deployment will be more difficult to accomplish than as many anticipate.

13/03640 Tidal stream energy site assessment via three-dimensional model and measurements

Work, P. A. *et al. Applied Energy*, 2013, 102, 510–519.

A methodology for assessment of the potential impacts of extraction of energy associated with astronomical tides is described and applied to a site on the Beaufort River in coastal South Carolina, USA. Despite its name, the site features negligible freshwater inputs; like many in the region, it is a tidal estuary that resembles a river. A three-dimensional, numerical, hydrodynamic model was applied for a period exceeding a lunar month, allowing quantification of harmonic constituents of water level and velocity, and comparison to values derived from measurements, recorded at a location within the model domain. The measurement campaign included surveys of bathymetry and velocity fields during ebb and flood portions of a tidal cycle for model validation. Potential far-field impacts of a generic tidal energy conversion device were simulated by introducing an additional drag force in the model to enhance dissipation, resulting in 10–60% dissipation of the pre-existing kinetic power within a flow cross-section. The model reveals effects of the dissipation on water levels and velocities in adjacent areas, which are relatively small even at the 60% dissipation level. A method is presented to estimate the optimal vertical location for the energy conversion device and the potential power sacrificed by moving to a different altitude.

13/03641 Wave farm impact based on realistic wave-WEC interaction

Carballo, R. and Iglesias, G. *Energy*, 2013, 51, 216–229.

The objective of this work is to investigate the impact of a wave farm on the nearshore wave climate quantifying, for the first time, the interaction of the wave energy converters (WECs) with the waves using *ad hoc* laboratory tests. To accomplish this objective, a procedure consisting of three main steps is implemented and illustrated with a case study: a wave farm of WaveCats (a lateral overtopping WEC) proposed for the Death Coast (north-west Spain). First, the wave climate in the wave farm area is characterized and reference wave conditions are established. Second, wave–WEC interaction and, more specifically, wave energy transmission is determined by means of three-dimensional physical model tests. Third, on the basis of the results of the laboratory tests, the impact of different layouts of the wave farm (single-row and two-row arrays) on the nearshore wave climate is computed using a high-resolution spectral wave model. The results indicate that the difference between the two layouts is negligible at a distance of 5000 m or greater past the farm. Although the case study concerns a specific WEC and area of deployment, the procedure is entirely general in that it can be applied to other WECs and areas of interest.

13/03642 Experiment of catalyst activity distribution effect on methanol steam reforming performance in the packed bed plate-type reactor

Wang, G. *et al. Energy*, 2013, 51, 267–272.

Methanol reforming is considered as a promising candidate for hydrogen production because of its advantages in many ways. Conventional reformers of packed-bed catalyst suffer from severe limitations of mass and heat transfer. These disadvantages result in a low catalyst effectiveness factor in the conventional pellet catalyst. In this work, a plate-type reactor has been developed to investigate the influence of catalyst activity distribution on methanol steam reforming. Cold spot temperature differences are observed in the temperature profile along the reactor axis. It has been experimentally verified that reducing cold spot temperature differences contributes to the improvement of the catalytic hydrogen production. The minimal cold spot temperature difference is obtained on the optimal catalyst distribution. It is found that the optimal catalyst distribution shows superiority in the methanol conversion and H_2 production rate in comparison to that of the other ones.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

13/03643 A marginal measure of energy efficiency: the shadow value

Khademvatani, A. and Gordon, D. V. *Energy Economics*, 2013, 38, 153–159.

Economists are well aware of the importance of marginal versus average measures of energy efficiency. Yet in the energy literature, there is no consensus on the appropriate method for defining and measuring energy efficiency. This paper sets out the shadow value of energy as a proper and meaningful marginal energy efficiency index. A restricted profit function is used to model the shadow value. The authors explore four scenarios to characterize and evaluate the shadow value of energy; a within country comparison of different production processes with different energy requirements, a comparison of different countries with different resource endowment, a government policy to impose a tax to alter the shadow value to address environmental issues and a within country comparison of externalities arising from two sources of energy. A comparative static analysis is carried out to sign the functional arguments defined for the shadow value.

13/03644 A non-parametric method for correction of global radiation observations

Bacher, P. *et al. Solar Energy*, 2013, 88, 13–22.

This paper presents a method for correction and alignment of global radiation observations based on information obtained from calculated global radiation, in the present study one-hour forecast of global radiation from a numerical weather prediction (NWP) model is used. Systematical errors detected in the observations are corrected. These are errors such as: tilt in the levelling of the sensor, shadowing from surrounding objects, clipping and saturation in the signal processing, and errors from dirt and wear. The method is based on a statistical non-parametric clear-sky model which is applied to both the observed and the calculated radiation in order to find systematic deviations between them. The method is applied to correct global radiation observations from a climate station located at a district heating plant in Denmark. The results are compared to observations recorded at the Danish Technical University. The method can be useful for optimized use of solar radiation observations for forecasting, monitoring, and modelling of energy production and load which are affected by solar radiation.

13/03645 A passive method of water management for an air-breathing proton exchange membrane fuel cell

Kumar, P. M. and Parthasarathy, V. *Energy*, 2013, 51, 457–461.

Water management in an AB-PEMFC (air-breathing proton exchange membrane fuel cell) poses a big challenge due to its passive operation. The issue is addressed in a passive way by designing the fuel cell with low thermal conductivity materials. Use of low thermal conductivity materials for cell fabrication led to higher cell temperatures. The liquid water formation was delayed to high current densities due to increase in saturation pressure and higher buoyancy induced flow. Peak power density was increased by 36% and the limiting current density was increased by 37.5% when the cell was redesigned with low thermal conductivity materials. Fabricating the cells with low thermal conductivity materials can be very effective method of water management for air-breathing single proton exchange membrane fuel cells and stacks of low capacity.

13/03646 A study about the demand for air movement in warm environment

Huang, L. *et al. Building and Environment*, 2013, 61, 27–33.

As the main regulation tool of indoor thermal environment in warm seasons, air-conditioners are used to keep a cool environment. However, this causes problems of huge energy consumption and poor indoor air quality. In contrast, electric fans promise an indoor cooling effect with lower energy consumption. This makes the exploration of air flow utilization significant. This paper discusses the results of a research with both an online survey and a series of climate chamber experiment to study user requirements for air movement in their daily life. The online survey results showed that electric fans were widely accepted in both homes and offices because they were environmental friendly, low-cost and could provide a fresh feeling. The results of climate chamber experiment identified suitable range of indoor temperature to use electric fans and their corresponding range of air speeds. The air flow generated by electric fans could be used as an effective cooling method to maintain a comfortable environment at 28–32 °C. Compared with the acceptable range of temperature and air speeds for the comfort zone recommended by the ASHRAE Standard 55–2010, this study showed that air speeds over 0.8 m/s were acceptable and they could offset a higher temperature. With reasonable utilization, electric fans could provide a healthy and energy-efficient way to control indoor environment.

13/03647 An adaptive modified firefly optimisation algorithm based on Hong's point estimate method to optimal operation management in a microgrid with consideration of uncertainties

Mohammadi, S. *et al. Energy*, 2013, 51, 339–348.

A probabilistic energy management system to optimize the operation of the micro-grid (MG) based on an efficient point estimate method (PEM) is proposed in this paper. This method is used to model the uncertainty in the power generation of the wind farms and the photovoltaic (PV) systems, the market prices and the load demands. PEMs constitute a remarkable tool to handle stochastic power system problems because good results can be achieved by using the same routines as those corresponding to deterministic problems, while keeping the computational burden low. For a system with m uncertain parameters, it uses $2m + 1$ calculations of cost function to calculate the statistical moments of cost function solution distributions by weighting the value of the solution evaluated at $2m + 1$ locations. The moments are then used in the probability distribution fitting. The normal, Beta and Weibull distributions are used to handle the uncertain input variables. Moreover, an adaptive modified firefly algorithm (AMFA) is employed to achieve an optimal operational planning with regard to cost minimization. Performance of the proposed method is verified using a typical MG.

13/03648 An investigation of thermo-compressor design by analysis and experiment: part 1. Validation of the numerical method

Sharifi, N. and Boroomand, M. *Energy Conversion and Management*, 2013, 69, 217–227.

Thermal vapour compressors are the main part of desalination systems and directly influence the overall efficiency of the systems. In order to improve the design of a thermal vapour compressor (TVC), it is necessary to understand the flow field inside such devices. This study will be presented in two separate parts. The main objective of the first part is to prepare and validate a numerical method to investigate the flow pattern within a conventional TVC. Two numerical schemes on the basis of axisymmetric and three-dimensional assumptions are implemented to analyse the performance parameters. The results of both models are compared with the experimental measurements obtained from an industrial desalination unit. It is shown that the axisymmetric model is quite capable of producing similar results to three-dimensional model, and both results are in acceptable agreements with the experimental data. Verification of the numerical method enables us to introduce a new design methodology in the second part of this study.

13/03649 An investigation of thermo-compressor design by analysis and experiment: part 2. Development of design method by using comprehensive characteristic curves

Sharifi, N. and Boroomand, M. *Energy Conversion and Management*, 2013, 69, 228–237.

In the first part of this study, the numerical evaluation of the thermo-compressor performance was validated with the experimental data and a precise computational fluid dynamics method for studying the internal flow was presented. The reliable simulation approach will enables the introduction of a design methodology for geometry selection for a thermo-compressor under the known operating conditions. In this study, some important shape parameters of a conventional thermo-compressor will be introduced and the influence of these parameters on the overall performance will be investigated. In a further step, a wide range of geometrical parameters will be presented through the use of validated numerical method, and a collection of design curves will be produced. Finally, a practical relationship between characteristic parameters and non-dimensional geometrical parameters will be revealed. The objective of this work is to develop the design diagrams in order to establish a robust procedure for designing thermo-compressors with several facilities that one should expect from a standalone group of design charts. If the results of this procedure are carefully implemented to select shape parameters, a remarkable improvement to the overall performance of a thermo-compressor will be achieved perceptibly.

13/03650 Analysis of carbohydrates by atmospheric pressure chloride anion attachment tandem mass spectrometry

Vinueza, N. R. *et al. Fuel*, 2013, 105, 235–246.

The ability to characterize oligosaccharides directly in complex mixtures would greatly benefit many research efforts focused on the development of biofuels from lignocellulosic biomass. The authors report here on the utility of chloride anion attachment in atmospheric pressure chemical ionization (APCI) and electrospray ionization (ESI) tandem mass spectrometry for molecular weight determination and structural elucidation of several monosaccharides, disaccharides and oligosaccharides directly without sample pretreatment or derivatization. Chloride anion forms stable adducts with these sugars on ESI or APCI, which can be readily identified due to the chlorine isotope pattern. Fragment anions or other product anions are usually not observed, which is beneficial for mixture analysis. Upon collisional activation in MS^2 experiments, these adducts readily lose HCl, which helps verify the molecular weight of each analyte. Isolating the resulting anion and subjecting it to further collision-activated dissociation experiments (MS^n; $n = 3–4$) until no ion signal remains yields useful structural information. Examination of equimolar mixtures of monosaccharides, disaccharides and oligosaccharides and mixtures of enzymatically digested biomass demonstrates the ability of this methodology to ionize all the components of the mixtures without bias and with nearly equal efficiency.

13/03651 Application of continuous surface temperature monitoring technique for investigation of nocturnal sensible heat release characteristics by building fabrics in Hong Kong

Sham, J. F. C. *et al. Energy and Buildings*, 2013, 58, 1–10.

This study applied a novel technique, continuous surface temperature monitoring (CSTM) that uses infrared technology, for deriving *in situ* sensible heat released by different building fabrics in Kowloon Tong, Hong Kong. Five possible factors (finish materials, colours of finish materials, size of the building, orientation, and seasonal change) which may affect the cooling pattern/sensible heat release characteristics of building fabrics were studied. Cooling patterns of building fabrics of different sizes were found to be same. Therefore, CSTM technique can be applied to capture thermal data of a large number of buildings simultaneously for sensible heat analysis. In general, granite wall releases more sensible heat than aluminium and ceramic tile wall. It was found that difference between colours is not as significant as difference in finish materials. The maximum surface temperature (peak) of walls facing east appears earlier than those facing west. Significant differences between energy released by building fabrics in hot and cold seasons was also found. However, the proportion of sensible heat released by the buildings to the global solar radiation (GSR) was similar in both seasons. Hence, it holds that the percentage of sensible heat release against the total GSR is quite constant in hot and cold season.

13/03652 Calculation of the power factor using the neutron diffusion hybrid equation

da Silva, A. C. *et al. Annals of Nuclear Energy*, 2013, 51, 240–243.

This study used a neutron diffusion hybrid equation with an external neutron source to calculate nuclear power factors in each fuel element in the reactor core. The nodal expansion method was used to obtain the neutron flux for a given control rods bank position. The results were compared with results obtained for eigenvalue problem near criticality condition and fixed source problem during the start-up of the reactor, where external neutron sources are extremely important for the stabilization of external neutron detectors.

13/03653 Control design and dynamic simulation of an HMR pre-combustion power cycle based on economic measures

Zhao, L. *et al. Energy*, 2013, 51, 171–183.

This paper studies dynamic behaviour and control design of a hydrogen membrane reforming (HMR) power cycle based on economic measures. The HMR power cycle is a novel pre-combustion capture power cycle for electrical power production which incurs less of an energy penalty than current post combustion technologies. However, the HMR power cycle consists of a novel reformer and complex heat integration. For this type of power cycle to be competitive, it is important to have a thorough understanding of the system dynamics including robust control design which secures reasonable rejection of all important disturbances and tracking of desired outputs like load and CO_2 capture flow rates. First, a new dynamic model of the HMR power cycle aimed at control design is developed based on first principles. It is further validated against existing knowledge. Dynamic behaviour of the critical components as well as the whole plant is investigated based on the model. Then, control structures of the power cycle are designed by a systematic approach. The simulation results show that the control structure depends on the CO_2 price. Not surprisingly, when the cost of CO_2 emissions is low, the optimal operation is found at the lowest possible CO_2 capture rate. When the price of CO_2 emissions is increased to €1.50/kmol, CO_2 capture rate is no longer constrained at 90%. Two different controlled variables, i.e. single measurement, and combined measurements, are found from self-optimizing control. The advantage of selecting the single measurement is that minimal changes of the control structure are required when the operating conditions are changed. This is because the steam to carbon (S/C) ratio is also an optimal active constraint in the case of low CO_2 price and is active in the presence of large disturbances, e.g. load reduced to below 300 MW. The combined measurement variable gives the minimal loss at high CO_2 price. However, it requires more measurements which may increase the cost.

13/03654 Daylighting in buildings: developments of sunlight addressing by optical fiber

Sapia, C. *Solar Energy*, 2013, 89, 113–121.

In this work is presented a study on the use of the optical fibre and a solar concentrator for a daylighting addressing system in buildings. The solar energy, in the form of light, collected through a sun-tracking parabolic concentrator system, is guided and addressed in the chosen area of the building with an opportune fibre optics guiding structure. A solar lighting system by optical fibre turns out convenient from a point of view of energy saving and in terms of respect of the environment for the resultant reduction in greenhouse gas emissions. Daylighting can, moreover, influence positively the well-being degree: improves visual quality and comfort reducing, for example, the psychological sadness related to the seasonal affective disorder. The hybrid sunlight addressing/near infra-red PV systems under development is composed by a primary parabolic collector which concentrates solar light to a secondary flat optical reflector made by a series of cold mirrors. These elements are frequency selective, so that only the visible range of the solar spectrum is reflected to 'light' optical fibre bundles. The near infra-red part of the solar spectrum is transmitted over to feed photovoltaic cells to get energy for artificial lighting needs at night. By frequency selection the working area of the building is illuminated without the thermal load connected to the infrared portion of the solar radiation. Setting the required ambient light output, with the aid of the principles of the telecommunications antennas, it has been implemented a procedure in MATLAB for sizing of the primary parabolic concentrator and the secondary reflector. It is, therefore, defined the point of optimal positioning of the circular crown of the bundles of optical fibre. The overall system cost is also estimated. Some considerations on the economic dimensioning of the system in terms of efficiency, estimated annual medium energy saving and expected time of economic amortization are discussed. Using the described sunlight addressing system it is possible to avoid the energy 'double-conversion'. Lighting of building interiors by PV conversion of solar light into electricity and then again into (artificial) light is a low efficiency lighting solution. The direct use of sunlight should be preferred in lighting of rooms with predominant diurnal occupancy, such as classrooms, libraries and laboratories.

13/03655 Determination of fluid-flow zones in a geothermal sandstone reservoir using thermal conductivity and temperature logs

Haffen, S. *et al. Geothermics*, 2013, 46, 32–41.

A new methodology for locating fluid-flow zones in a rock formation is proposed and applied to the Buntsandstein sandstone reservoir penetrated by borehole EPS1, Soultz-sous-Forêts, France. The method is based on analysing thermal gradients obtained by two different methods for the same cored borehole, (1) from temperature log and (2) from thermal conductivity measurements. Comparing the two thermal-gradient datasets reveals the fluid-circulation zones in the borehole. Using this approach, three main hot-fluid circulation zones were identified within the Buntsandstein reservoir, two controlled by sedimentary facies and one controlled by tectonic structures.

13/03656 Electrical earthing in troubled environment

Lim, S. C. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 117–128.

Practical challenges of electrical earthing in both steady and transient states have been revisited. By analysing the cases based on theoretical and practical aspects, engineering guidelines are proposed to develop suitable solutions. Less complicated cases can be approached with various electrode configurations such as multiple ring, antenna, crow-foot and centipede arrangements. Distributed earthing arrangements treated with backfill materials are suitable for the sites with extremely high resistive soil. Clay based backfill materials such as bentonite-mix give corrosion and erosion protection for the electrodes in highly acidic, alkaline, saline and sulfur-rich environments apart from reducing the low frequency resistance. On-rock sites such as transmission and communication towers are better approached with concrete-based earthing systems in both cases of power and lightning protection earthing. Extreme cases of soil instability have been identified and discussed. The suitability of vertical and horizontal electrode components as well as copper and steel electrodes under various soil conditions is also discoursed. For most cases, the authors recommend all types of earthing systems to be integrated, however, properly coordinated system of surge protective devices should be incorporated in such integrated earthing system.

13/03657 Electrochemical reduction of CO_2 over Sn-Nafion® coated electrode for a fuel-cell-like device

Surya Prakash, G. K. *et al. Journal of Power Sources*, 2013, 223, 68–73.

Commercially available Sn particles mixed with Nafion® ionomer are used to prepare an electrode with a gas diffusion layer support in a manner similar to that in which fuel cell electrodes are prepared. Cyclic voltammetry is performed in aqueous $NaHCO_3$ (basic medium) on the electrode and the Tafel parameters are obtained and compared with a Sn metal disc and with a graphite disc coated with Sn powder. In addition, electrolysis is carried out potentiostatically, also in $NaHCO_3$ solution, at various potentials. The exchange current density on the Sn/gas diffusion layer electrode shows to be two orders of magnitude higher that on the metallic Sn disc. The maximum current density obtained during electrolysis is $27\,\mathrm{mA\,cm^{-2}}$ at -1.6 V vs NHE, with 70% faradaic efficiency towards the formation of formate, which is one of the highest values found in the literature on Sn electrode at ambient pressure.

13/03658 Energy harvesting from salinity gradient by reverse electrodialysis with anodic alumina nanopores

Kim, J. *et al. Energy*, 2013, 51, 413–421.

Power generation by reverse electrodialysis from anodic alumina nanopores is experimentally investigated by placing an alumina nanopore array with a nominal pore radius of 10 nm between two sodium chloride solutions with various combinations of concentrations. Both bare and silica-coated alumina nanopore arrays are used in the present study. The current–potential characteristics are measured for various electrolyte concentration levels, and the transference number and the electrical conductance of the nanopore arrays are obtained from these characteristics. The transference numbers of the bare and silica-coated alumina nanopore arrays are 0.30 and 0.72, respectively; these values are nearly independent of the concentration of the sodium chloride solutions when it is less than 200 mM. Therefore, the bare and silica-coated alumina arrays can be used as anion selective and cation selective membranes, respectively, for micro batteries and micro power generators. Finally, power generation by reverse electrodialysis using an alumina nanopore array is presented. The highest power generation measured is 542 nW, which is several orders of magnitude higher than those measured in previous studies based on nanofluidic channels or nanopores.

13/03659 Energy loss distribution of proton beams at normal incidence on multi-walled carbon nanotubes

Valdés, J. E. *et al. Carbon*, 2013, 52, 137–144.

The irradiation with energetic proton beams impinging normal to the axis of a multi-walled carbon nanotube (MWCNT) is studied both experimentally and theoretically, in the 2–10 keV energy range. The MWCNTs are dispersed on top of a very thin film of holey amorphous carbon substrate. Measurements of the proton energy loss distribution are performed after MWCNT irradiation with energetic proton beams by the transmission technique. The resulting energy loss spectra in the forward direction show two well differentiated peaks, whose origin is elucidated by using a semi-classical simulation of the proton trajectory through the nanotube. It was found that the experimental lower-energy loss peak mostly comes from protons travelling between the outer walls of the MWCNT, whereas the high-energy loss peak is mainly due to protons that interact with the MWCNTs just on top of the supporting amorphous carbon substrate.

13/03660 Fast pyrolysis of coconut biomass – an FTIR study

Siengchum, T. *et al. Fuel*, 2013, 105, 559–565.

The reaction pathway of coconut shell fast pyrolysis was studied by analysis of the transient evolution product profiles as a function of temperature, measured directly in the sample bed. Fast pyrolysis of coconut shell produced (i) pyrolysis liquid containing C–H, C=O, and C–O–C bands, (ii) char with the absence of C–OH and C=O suggesting that ether and carbonyl compounds were decomposed below 600 °C, and (iii) gaseous product majorly consisting of CO_2. Increase the heating rate has a greater effect on increasing the yield of aliphatic and carbonyl compounds compared to that of aromatic compounds. The selectivity of the fast pyrolysis liquid was shifted from vinyl species to carbonyl species at temperatures between 500 and 615 °C. *In situ* infrared study suggests that CO and CO_2 were mainly produced from cracking of C–H and C=O bonds. Fast pyrolysis of D_2O-saturated coconut shell showed that moisture in the biomass does not increase the H_2 yield at high temperature and H_2 is mainly produced from breaking of C–H bonds.

13/03661 Frictional resistance of adiabatic two-phase flow in narrow rectangular duct under rolling conditions

Xing, D. *et al. Annals of Nuclear Energy*, 2013, 53, 109–119.

Frictional resistance of air-water two-phase flow in a narrow rectangular duct subjected to rolling motion was investigated experimentally. Time-averaged and transient frictional pressure drop under rolling condition were compared with conventional correlation in laminar flow region ($Re_l < 800$), transition flow region ($800 \leq Re_l \leq 1400$) and turbulent flow region ($Re_l > 1400$), respectively. The result shows that, despite no influence on time-averaged frictional resistance, rolling motion does induce periodical fluctuation of the pressure drop in laminar and transition flow regions. Transient frictional pressure drop fluctuates synchronously with the rolling motion both in laminar and in transition flow region, while it is nearly invariable in turbulent flow region. The fluctuation amplitude of the relative frictional pressure gradient decreases with the increasing of the superficial velocities.

13/03662 Gas geochemistry of the magmatic-hydrothermal fluid reservoir in the Copahue–Caviahue Volcanic Complex (Argentina)

Agusto, M. *et al. Journal of Volcanology and Geothermal Research*, 2013, 257, 44–56.

Copahue volcano is part of the Caviahue–Copahue volcanic complex (CCVC), which is located in the southwestern sector of the Caviahue volcano-tectonic depression (Argentina–Chile). This depression is a pull-apart basin accommodating stresses between the southern Liquiñe–Ofqui strike slip and the northern Copahue–Antiñir compressive fault systems, in a back-arc setting with respect to the southern Andean volcanic zone. In this study presents chemical (inorganic and organic) and isotope compositions ($\delta^{13}C$-CO_2, $\delta^{15}N$, $^3He/^4He$, $^{40}Ar/^{36}Ar$, $\delta^{13}C$-CH_4, δD-CH_4, and δD-H_2O and $\delta^{18}O$-H_2O) of fumaroles and bubbling gases of thermal springs located at the foot of Copahue volcano sampled in 2006, 2007 and 2012. Helium isotope ratios, the highest observed for a southern American volcano (R/R_a up to 7.94), indicate a non-classic arc-like setting, but rather an extensional regime subdued to asthenospheric thinning. $\delta^{13}C$-CO_2 values (from −8.8‰ to −6.8‰ vs V-PDB), $\delta^{15}N$ values (+ 5.3‰ to + 5.5‰ vs air) and $CO_2/^3He$ ratios (from 1.4 to 8.8×10^9) suggest that the magmatic source is significantly affected by contamination of subducted sediments. Gases discharged from the northern sector of the CCVC show contribution of ^3He-poor fluids likely permeating through local fault systems. Despite the clear mantle isotope signature in the CCVC gases, the acidic gas species have suffered scrubbing processes by a hydrothermal system mainly recharged by meteoric water. Gas geothermometry in the H_2O-CO_2-CH_4-CO-H_2 system suggests that CO and H_2 re-equilibrate in a separated vapour phase at 200°–220 °C. On the contrary, rock–fluid interactions controlling CO_2, CH_4 production from Sabatier reaction and C_3H_8 dehydrogenation seem to occur within the hydrothermal reservoir at temperatures ranging from 250 to 300 °C. Fumarole gases sampled in 2006–2007 show relatively low N_2/He and N_2/Ar ratios and high R/R_a values with respect to those measured in 2012. Such compositional and isotope variations were likely related to injection of mafic magma that likely triggered the 2000 eruption. Therefore, changes affecting the magmatic system had a delayed effect on the chemistry of the CCVC gases due to the presence of the hydrothermal reservoir. However, geochemical monitoring activities mainly focused on the behaviour of inert gas compounds (N_2 and He), should be increased to investigate the mechanism at the origin of the unrest started in 2011.

13/03663 Gas recycling in fluidized bed to avoid defluidization for reactions accompanied by decrease in the number of moles

Kai, T. *et al. Chemical Engineering Journal*, 2013, 215–216, 671–677.

A gas recycling method for establishing stable operations of a fluidized catalyst bed is studied in order to perform reactions accompanied by a decrease in the number of moles. Two operation modes using gas recycling are evaluated to prevent defluidization and establish stable operation. For the first operation mode, because the influence of the decrease in the number of moles on the fluidization quality is reduced by adding a dilute gas to the feed, the reactor is operated with high conversion and a part of the outlet gas is recycled to the reactor inlet. The fluidization quality is also improved by decreasing the reaction rate. Therefore, for the second mode, the reactor is operated with low conversion, and the unreacted components in the outlet gas are separated from the product gas and recycled to the reactor inlet. It is possible to increase the overall conversion to a high level by gas recycling. Experimental data in previous studies and a fluidized-bed-reactor model that considers the decrease in the number of moles are used in order to determine the required recycle ratio and reaction rate constant for establishing a stable operation. Even when a reaction is accompanied by a 50% decrease in the number of moles, the required recycle ratio is below 9 for the recycle mode without separation and below 5.5 for the recycle mode with separation.

13/03664 General models for estimating daily global solar radiation for different solar radiation zones in mainland China

Li, M.-F. *et al. Energy Conversion and Management*, 2013, 70, 139–148.

Empirical models, proposed to estimate solar radiation (Rs) in various areas, were site-specific in essence. However, it is questionable when they are applied to other stations where there is no record of Rs. This study aimed to develop general models to estimate daily Rs for different solar radiation zones in mainland China. Daily weather data including Rs, sunshine duration, relative humidity, maximum and minimum temperatures were collected and analysed from 83 stations. Two types of simple empirical equations, namely, temperature- and sunshine-based models, were obtained for each site. Five Rs zones were determined by *k*-smeans clustering algorithm based on long-term mean daily Rs. For each zone, the general model for Rs estimation was developed based on geographical factors (latitude, longitude and altitude) and site-specific models. Coefficient of residual mass, mean bias error, mean percentage error, root mean square error and percentage root mean square error were used to investigate the model performance. The comparative results between measured and estimated daily Rs showed that the general models had an acceptable accuracy. It is believed that the general models developed in this work can be reliable and applicable for the locations without available Rs data in mainland China.

13/03665 Inference of the biodiesel cetane number by multivariate techniques

Nadai, D. V. *et al. Fuel*, 2013, 105, 325–330.

This study implements a method which uses structural information from ^{1}H NMR spectra of fatty esters and biodiesels to infer the corresponding cetane number (CN). The method consists of the successive application of principal component analysis (PCA), fuzzy clustering and a feed-forward artificial neural network (ANN) to the data set. PCA recognized redundant information, and determined the number of clusters for subsequent fuzzy clustering classification. At the final stage ANN used membership values from the fuzzy clustering process as inputs to predict the cetane number of different types of biodiesel (complex mixtures) from data of pure substances (esters). Root-mean-square deviations were in the range of 0.2–2.4.

13/03666 Lagrangian–Eulerian methods for multiphase flows

Subramaniam, S. *Progress in Energy and Combustion Science*, 2013, 39, (2–3), 215–245.

This review article aims to provide a comprehensive and understandable account of the theoretical foundation, modelling issues, and numerical implementation of the Lagrangian–Eulerian (LE) approach for multiphase flows. The LE approach is based on a statistical description of the dispersed phase in terms of a stochastic point process that is coupled with a Eulerian statistical representation of the carrier fluid phase. A modelled transport equation for the particle distribution function – also known as Williams' spray equation in the case of sprays – is indirectly solved using a Lagrangian particle method. Interphase transfer of mass, momentum and energy are represented by coupling terms that appear in the Eulerian conservation equations for the fluid phase. This theoretical foundation is then used to develop LE sub-models for interphase interactions such as momentum transfer. Every LE model implies a corresponding closure in the Eulerian–Eulerian two-fluid theory, and these moment equations are derived. Approaches to incorporate multiscale interactions between particles (or spray droplets) and turbulent eddies in the carrier gas that result in better predictions of particle (or droplet) dispersion are described. Numerical convergence of LE implementations is shown to be crucial to the success of the LE modelling approach. It is shown how numerical convergence and accuracy of an LE implementation can be established using grid-free estimators and computational particle number density control algorithms. This review of recent advances establishes that LE methods can be used to solve multiphase flow problems of practical interest, provided sub-models are implemented using numerically convergent algorithms. These insights also provide the foundation for further development of Lagrangian methods for multiphase flows. Extensions to the LE method that can account for neighbour particle interactions and preferential concentration of particles in turbulence are outlined.

13/03667 Nanoferrofluid addition enhances ammonia/water bubble absorption in an external magnetic field

Wu, W.-D. *et al. Energy and Buildings*, 2013, 57, 268–277.

The absorber is one of the most critical components to consider in the improvement of absorption refrigeration cycle performance. This study investigated the addition of an Fe_3O_4 nanoferrofluid in combination with the application of an external magnetic field as a new method for enhancing absorption in an ammonia/water bubble-type absorber and performed a detailed experimental study of its effects on bubble absorption. The results showed that the combined effect of the nanoferrofluid and the external magnetic field significantly enhanced ammonia/water bubble absorption, and the enhancement of the combined factors was greater than that by either factor alone under the same conditions. To obtain the greatest enhancement, the study also determined the optimal concentration of nanoferrofluid within the investigated range and found that absorption was further enhanced with increasing magnetic field intensity at a constant nanoferrofluid concentration. At an initial ammonia mass concentration of 20%, an Fe_3O_4 nanoferrofluid mass concentration of 0.10% and an external magnetic field intensity of 280 mT, the effective absorption ratio reached a maximum of 1.0812 ± 0.0001 under adiabatic condition. Finally, the mechanism of absorption enhancement by the nanoferrofluid and external magnetic field in this system was discussed.

13/03668 NMR a critical tool to study the production of carbon fiber from lignin

Foston, M. *et al. Carbon*, 2013, 52, 65–73.

The structural changes occurring to hardwood Alcell^{TM} lignin as a result of fibre devolatilization/extrusion, oxidative thermo-stabilization and carbonization are investigated in this study by solid-state and solution nuclear magnetic resonance (NMR) spectroscopy techniques. Solution-based ^{1}H–^{13}C correlation NMR of the un-spun Alcell^{TM} lignin powder and extruded lignin fibre detected modest changes occurring due to fibre devolatilization/extrusion in the type and proportion of aliphatic side-chain carbons or monolignol inter-unit linkages. Molecular weight analysis by gel permeation chromatography (GPC), along with an additional ^{31}P NMR method used to indicate changes in terminal hydroxyl functionality, suggest fibre devolatilization/extrusion causes both chain scission and condensation reactions. ^{1}H CRAMPS (combined rotation and multiple-pulse spectroscopy) and ^{13}C cross-polarization/magic angle spinning (CP/MAS) spectra of extruded and stabilized lignin fibres indicate stabilization severely reduces the proportion of methoxy groups present, while also increasing the relative proportion of carbonyl and carboxyl-related structures, typically associated with cross-linking chemistries. ^{13}C direct-polarization/magic angle spinning (DP/MAS) analysis of stabilized and carbonized fibres shows an increased relative amount of carbon–carbon bonds on aryl structures and a relative decrease of aryl ethers. DP/MAS dipolar dephasing experiments suggest that a majority of non-protonated carbons convert from carbonyl to aryl and condensed aryl structures during carbonization.

13/03669 Nuclear waste imaging and spent fuel verification by muon tomography

Jonkmans, G. *et al. Annals of Nuclear Energy*, 2013, 53, 267–273.

This paper explores the use of cosmic ray muons to image the contents of shielded containers and detect high-*Z* special nuclear materials inside them. Cosmic ray muons are a naturally occurring form of radiation, are highly penetrating and exhibit large scattering angles on high-*Z* materials. Specifically, the study investigated how radiographic and tomographic techniques can be effective for non-invasive nuclear waste characterization and for nuclear material accountancy of spent fuel inside dry storage containers. It is shown that the tracking of individual muons, as they enter and exit a structure, can potentially improve the accuracy and availability of data on nuclear waste and the contents of dry storage containers (DSCs) used for spent fuel storage at CANDU® plants. This could be achieved in near real time, with the potential for unattended and remotely monitored operations. The study shows that the expected sensitivity, in the case of the DSC, exceeds the IAEA detection target for nuclear material accountancy.

13/03670 Optical efficiency analysis of cylindrical cavity receiver with bottom surface convex

Wang, F. *et al. Solar Energy*, 2013, 90, 195–204.

The bottom surface of a conventional cavity receiver cannot be fully covered by coiled metal tube during fabrication, which would induce a dead space of solar energy absorption. The dead space of solar energy absorption can severely decrease the optical efficiency of cavity receiver. Two new types of cavity receiver with bottom surface convex were put forward with the objective to solve the problem of dead space of solar energy absorption and to improve the optical efficiency of cavity receiver. The optical efficiency and heat flux distribution of the two new types of cavity receiver were analysed using a Monte Carlo ray tracing method. The optical efficiency comparisons between conventional cavity receiver and the two new types of cavity receiver were conducted at different characteristic parameter conditions. It was concluded that the cylindrical with conical combined receiver cannot improve optical efficiency through the entire dimensionless height variation range, and there is a dimensionless height limiting for optical efficiency improving. Among the whole interior convex dimensionless height variation range, the optical efficiency of the bottom surface interior convex (BSIC) receiver is higher than that of conventional cylindrical cavity receiver with no dead space, and the BSIC receiver for dimensionless height of 0.875 has the highest optical efficiency. Among the whole wall absorptivity variation range, pointing error variation range and alignment variation range, the optical efficiency of BSIC receiver for a dimensionless height of 0.875 is higher than that of conventional cylindrical cavity receiver. The BSIC receiver can effectively reach the objective of optical efficiency improving.

13/03671 Predicting the biochemical methane potential of wide range of organic substrates by near infrared spectroscopy

Doublet, J. *et al. Bioresource Technology*, 2013, 128, 252–258.

The use of near infrared spectroscopy (NIRS) as an alternative method to predict the biochemical methane potential (BMP) of a broad range of organic substrates was investigated. A total of 296 samples including most of the substrates treated by anaerobic co-digestion were used for NIRS calibration and validation. The NIRS predictions of the BMP values were satisfactory (root mean square error = $40\,ml\,CH_4\,g^{-1}\,VS_{fed}$; $r^2 = 0.85$). The integration of the entire substrate diversity in the model remained nevertheless difficult due to the specific organic matter properties of stabilized substrates and the high level of uncertainty of the BMP values. The elaboration of a model restricted to 'fresh' substrates allows the practical use of the NIR technique to design and operate anaerobic co-digestion plants. The addition of more samples in the dataset in order to perform local calibrations would probably make the elaboration of a global NIR-model possible.

13/03672 Predicting the heating value of solid manure with visible and near-infrared spectroscopy

Preece, S. L. M. *et al. Fuel*, 2013, 106, 712–717.

Visible and near-infrared spectral data were used to predict the higher heating value (HHV) and dry, ash-free HHV (HHV_{daf}) of solid manure samples collected from cattle fed diets containing wet distillers grains plus solubles (WDGS) in 0%, 15%, 30%, 45%, and 60% dry matter concentrations. The HHV was determined by isoperibol bomb calorimetry and the HHV_{daf} was calculated from an equation based on the HHV and proximate analysis. Spectral models were developed in the 'Unscrambler' software. The spectral models based on all treatments with random samples withheld for validation predicted the HHV with excellent reliability within 1.7%; RMSD = $60.19\,\mathrm{cal\,g^{-1}}$ ($108\,\mathrm{Btu\,lb^{-1}}$), RPD = 2.29 (excellent), and bias = $-15.29\,\mathrm{cal\,g^{-1}}$ ($28\,\mathrm{Btu\,lb^{-1}}$), using five PLS factors and identifying 129 important wavebands. Accounting for estimated N and S content reduced the predictive accuracy of the spectral models by 0.1% with an RPD = 2.28 (excellent). Spectral models based on all treatments with random samples withheld for validation predicted the HHV_{daf} with acceptable reliability within 2.0% with an RMSD = $96.17\,\mathrm{cal\,g^{-1}}$ ($173\,\mathrm{Btu\,lb^{-1}}$), RPD = 1.17 (acceptable), and bias = $-19.83\,\mathrm{cal\,g^{-1}}$ ($-37\,\mathrm{Btu\,lb^{-1}}$), using five PLS (partial least squares) factors and identifying 29 important wavebands. Spectral models reliably predicted the HHV of feedlot manure with accuracy well under the 5% error margin tolerated in practical applications such as feedlot manure gasification.

13/03673 Probing carbon edge exposure of iron phthalocyanine-based oxygen reduction catalysts by soft X-ray absorption spectroscopy

Niwa, H. *et al. Journal of Power Sources*, 2013, 223, 30–35.

Recently carbon-based catalysts have attracted much attention for its high ability to catalyse oxygen reduction reaction (ORR) in a cathode for polymer electrolyte fuel cells. Among active site models of the catalyst, edge region of sp^2 carbon network is expected to demonstrate high ORR activity comparable to platinum catalysts. However, it is difficult to directly identify the chemical structure of the edge sites by applying conventional structural or electronic probes to actual catalysts. Here, the authors used C 1*s* X-ray absorption spectroscopy to observe electronic structure of carbon in iron phthalocyanine-based catalysts, and found a signature of edge exposure below the Π^* edge, whose intensity is well correlated with the ORR activity. Combined with information about the chemical structure of nitrogen, ORR activity of the catalyst is characterized in terms of the edge exposure.

13/03674 Seasonal and temporal characterization of dissolved organic matter in rainwater by proton nuclear magnetic resonance spectroscopy

Seaton, P. J. *et al. Atmospheric Environment*, 2013, 65, 52–60.

Dissolved organic carbon in rainwater was concentrated by two separate techniques and characterized by ^{1}H-NMR. The total ^{1}H-NMR integral of lyophilized rainwater was higher in every rain sample than that of C18 solid phase extracted samples and always contained a higher percentage integral in the region of protons bound to carbon atoms singly bound to oxygen (H–C–O), such as alcohols, polyols and carbohydrate-like compounds. C18 extracted samples had higher percentage integral in the alkyl region, consistent with reverse phase extraction of more hydrophobic components in rainwater. Differences in both the ^{1}H-NMR integration and spectral pattern of lyophilized rainwater samples were especially apparent between spring and winter rains, with spring samples having higher percentage carbohydrate (H–C–O) signal and winter rains having higher percentage alkyl protons and a spectral pattern consistent with the presence of saturated fatty acids. Spring rains are characterized by lower percentage alkyl signal coupled with higher percentage H–C–O than all other events while marine winter events appear in regions characterized by relatively high percentage alkyl and average percentage H–C–O, consistent with increased abundance of fatty acids or fatty acid oxidation products. The ^{1}H-NMR data presented in this manuscript are important because they provide spectral data relating to the source and chemical characteristics of dissolved organic carbon in rainwater as a function of season and air mass back trajectory.

13/03675 Separation efficiency of a vacuum gas lift for microalgae harvesting

Barrut, B. *et al. Bioresource Technology*, 2013, 128, 235–240.

Low-energy and low-cost separation of microalgae from water is important to the economics of microalgae harvesting and processing. Flotation under vacuum using a vacuum gas lift for microalgae harvesting was investigated for different airflow rates, bubble sizes, salinities and harvest volumes. Harvesting efficiency (*HE*) and concentration factor (*CF*) of the vacuum gas lift increased by around 50% when the airflow rate was reduced from 20 to $10\,\mathrm{L\,min^{-1}}$. Reduced bubble size multiplied *HE* and *CF* 10 times when specific microbubble diffusers were used or when the salinity of the water was increased from 0‰ to 40‰. The reduction in harvest volume from 100 to 1 L increased the *CF* from 10 to 130. An optimized vacuum gas lift could allow partial microalgae harvesting using less than $0.2\,\mathrm{kWh\,kg^{-1}}$ DW, thus reducing energy costs 10–100 times compared to complete harvesting processes, albeit at the expense of a less concentrated biomass harvest.

13/03676 Sustain: an experimental test bed for building energy simulation

Greenberg, D. *et al. Energy and Buildings*, 2013, 58, 44–57.

Current building energy simulation technology requires extensive labour, time and expertise to create building energy models, substantial computational time for accurate simulations, and generates data in formats that make results difficult to interpret. These deficiencies can be ameliorated using modern graphical user interfaces and algorithms which take advantage of modern computer architectures and display capabilities. This paper describes a novel test bed environment which offers an interactive graphical interface, provides access to simulation modules that run at accelerated computational speeds, and presents new graphic visualization methods for the interpretation of simulation results. Its modular structure makes it suitable for use in early stage building design, for use as a research platform for the investigation of new simulation methods, and for use as a tool for teaching concepts of sustainable design. Improvements in the accuracy and execution speed of many of the simulation modules are based on the modification of advanced computer graphics rendering algorithms. Significant performance improvements are illustrated in several computationally expensive energy simulation modules.

13/03677 Synthesis of large surface area carbon xerogels for electrochemical double layer capacitors

Chang, Y.-M. *et al. Journal of Power Sources*, 2013, 223, 147–154.

A resorcinol–formaldehyde (R–F) condensation reaction catalysed by acetic acid (C) is employed to prepare carbon xerogels for electrochemical double layer capacitors. The samples are fabricated with an R:F ratio of 1:2 and R:C ratio of 10:1, followed by solvent exchange, pyrolysis, and carbon dioxide activation. The solvent exchange allows negligible structure contraction upon drying, and after pyrolysis and carbon dioxide treatment, porous carbons were produced with a surface area of $3419\,\mathrm{m^2\,g^{-1}}$. Scanning electron microscope images reveal an interconnected foam-like structure and BET confirms the presence of excessive micropores and mesopores. Electrochemical analysis including cyclic voltammetry (CV), current reversal chronopotentiometry (CRC), and impedance spectroscopy are conducted using a titanium cavity electrode so relevant capacitive characteristics and kinetic parameters could be determined. Both CV and CRC results indicate specific capacitances and life time behaviours that are comparable or even better than those of Black Pearl 2000. For example, the specific capacitance is $324.8\,\mathrm{F\,g^{-1}}$ in 0.5 M H_2SO_4 aqueous solution at $\pm1\,\mathrm{A\,g^{-1}}$ for potential window of 0–1 V. In contrast, sample without carbon dioxide activation displays a similar morphology but its surface area and specific capacitance are reduced considerably to $449\,\mathrm{m^2\,g^{-1}}$ and $34.7\,\mathrm{F\,g^{-1}}$, respectively.

13/03678 The characterisation of diesel nozzle flow using high speed imaging of elastic light scattering

Lockett, R. D. *et al. Fuel*, 2013, 106, 605–616.

Two identical, conventional six-hole, valve-covered orifice (VCO) diesel injectors have been modified in order to provide optical access to the region below the needle, and the nozzle-flow passages. This has been achieved through the removal of the metal tips, and their replacement with transparent acrylic tips of identical geometry. These two identical injectors were employed in order to offer comparability between the measurements. One of them had a dark, anodized inner surface at the base, while the other had a silvered inner surface at the base. Elastic scattering of incident white light from the internal cavitating flow inside the nozzle holes of the optically accessible diesel injector tips was captured on a high-speed electronic camera. The optical image data was obtained for three injector rail pressures ranging from 200 bar to 400 bar, and for five diesel fuels of varying density, viscosity, and distillation profile, in order to identify variations in cavitation flow behaviour inside the nozzle hole passages. A set of mean time-resolved diesel fuel flow images were obtained from 30 successive fuel injection pulses, for each operating condition, for each injector. The mean cavitation image occurring in the nozzle holes was converted to the mean proportion of nozzle hole area producing cavitation-induced optical scattering. The mean normalized area images were then analysed, and were able to demonstrate the anticipated inverse relationship between injected fuel mass and cavitation volume fraction (indicated by mean normalized area), and the effect of fuel viscosity and distillation profile on cavitation volume fraction (again indicated by mean normalized area).

13/03679 The impact of temperature on the rheological behaviour of anaerobic digested sludge

Baudez, J. C. *et al. Chemical Engineering Journal*, 2013, 215–216, 182–187.

The rheological properties of municipal anaerobic digested sludge rheology are temperature dependent. This study shows that both solid and liquid characteristics decrease with temperature. It also shows that the yield stress and the high shear (Bingham) viscosity are the two key parameters determining the rheological behaviour. By normalizing the shear stress with the yield stress and the shear rate with the yield stress divided by the Bingham viscosity, a master curve was obtained, independent of both temperature and concentration. The study also shows that the rheological behaviour is irreversibly altered by the thermal history. Dissolution of some of the solids may cause a decrease of the yield stress and an increase of the Bingham viscosity. This result suggests that the usual laws used to describe the thermal evolution of the rheological behaviour of fluids are no longer valid with anaerobic digested sludge. Finally, the impact of temperature and thermal history have to be taken into account for the design of engineering hydrodynamic processes such as mixing and pumping.

13/03680 The influence of the lattice relaxation on the optical properties of GaN_xAs_{1-x} alloys

Reshak, A. H. *et al. Solar Energy*, 2013, 90, 134–143.

This study investigated the optical properties of the ternary alloys GaN_xAs_{1-x} ($x = 0.25$, 0.5 and 0.75) without (called here case 1) and with (case 2) the lattice relaxation, using the full potential-linearized augmented plane wave (FP-LAPW) method. The exchange–correlation contribution was described within the generalized gradient approximation (GGA) to calculate the total energy, while for electronic properties in addition to that the Engel–Vosko (EVGGA) formalism was applied. In case 1, there is only optimized the lattice constant without relaxing the atomic positions, whereas in case 2 the atomic positions have been relaxed to find the equilibrium atomic configurations. The alloys were modelled at some selected compositions $x = 0.25$, 0.5 and 0.75 following the 'special quasirandom structures' (SQS) approach of Zunger to reproduce the randomness of the alloys for the first few shells around a given site. For relaxed alloys, the lattice constants vary linearly as function of composition x however, if internal relaxation is not allowed, significant deviations from Vegard's law occur. In general the imaginary part of the dielectric function of the two cases for each compositions look similar at the high energies while there is significant differences at the low energies. The reflectivity spectra, electron energy loss function and absorption coefficient are also calculated and analysed. Taking in consideration the lattice relaxation effect, the results are more reliable.

13/03681 The use of diffuse reflectance mid-infrared spectroscopy for the prediction of the concentration of chemical elements estimated by X-ray fluorescence in agricultural and grazing European soils

Soriano-Disla, J. M. *et al. Applied Geochemistry*, 2013, 29, 135–143.

The aim of this study was to develop partial least-squares (PLS) regression models using diffuse reflectance Fourier transform mid-infrared (MIR) spectroscopy for the prediction of the concentration of elements in soil determined by X-ray fluorescence (XRF). A total of 4130 soils from the GEMAS European soil sampling programme (geochemical mapping of agricultural soils and grazing land of Europe) were used for the development of models to predict concentrations of Al, As, Ba, Ca, Ce, Co, Cr, Cs, Cu, Fe, Ga, Hf, K, La, Mg, Mn, Na, Nb, Ni, P, Pb, Rb, Sc, Si, Sr, Th, Ti, V, Y, Zn and Zr in soil using MIR spectroscopy. The results were compared with those obtained where MIR models were developed with the same soils but using the concentration of elements extracted with aqua regia (AR). The PLS models were cross-validated against the experimental log-transformed XRF values of all the elements. The calibration models were derived from a set of 1000 randomly selected calibration samples. The rest of the samples (3130) were used as an independent validation set. According to the residual predictive deviation (RPD), predictions were classified as follows: 'Good quality', Ca (2.9), Mg (2.5), Al (2.3), Fe (2.2), Ga (2.2), Si (2.1), Na (2.0); 'Indicator quality', V (1.9), Ni (1.9), Sc (1.9), K (1.8), Ti (1.8), Rb (1.8), Zn (1.7), Co (1.7), Zr (1.6), Cr (1.6), Sr (1.6), Y (1.6), Nb (1.6), Ba (1.5), Mn (1.5), As (1.5), Ce (1.5); 'Poor quality', Cs (1.4), Th (1.4), P (1.4), Cu (1.4), Pb (1.3), La (1.2), Hf (1.1). Good agreement was observed between the RPD values obtained for the elements analysed in this study and those from the AR study. Despite the different elemental concentrations determined by the XRF method compared to the AR method, MIR spectroscopy was still capable of predicting elemental concentrations.

13/03682 Water transport and Schröder's paradox in fuel cell membrane electrode assemblies

Yau, T. C. *et al. Journal of Power Sources*, 2013, 224, 285–289.

In this work, water crossover between anode and cathode compartments of a PEM fuel cell was studied. A net water transport from cathode to anode under zero current was observed when the fuel cell was operated with saturated and oversaturated gases on anode and cathode, respectively. An additional pressure gradient of 0.5 bar from anode to cathode showed no significant influence on water crossover rate. The relevance of these observations to Schröder's paradox as well as implications for the explanation of water crossover results in a running fuel cell are discussed.

Fuel cell technology

13/03683 A new model for state-of-charge (SOC) estimation for high-power Li-ion batteries

He, Y. *et al. Applied Energy*, 2013, 101, 808–814.

The state-of-charge (SOC) is an important evaluation index for power battery systems in electric vehicles. To eliminate the effects of drift noise in the current sensor, a new working model that takes the drift current as a state variable is proposed for high-power Li-ion batteries. In conjunction with this result, a total available capacity expression that involves the temperature, charge–discharge rate, and running mileage as variables is reconstructed by the actual operation data to improve the model accuracy for application to electric vehicles. Then, to suppress the parameter perturbations of the working model, the unscented particle filter (UPF) method is applied to estimate the SOC. Experiments and numerical simulations are conducted to verify the superiority of the working model and the UPF method. The results show that the UPF method based on the working model can improve the accuracy and the robustness of the SOC estimation.

13/03684 A novel concept for improved thermal management of the planar SOFC

Vijay, P. *et al. Chemical Engineering Research and Design*, 2013, 91, (3), 560–572.

A new design for the solid oxide fuel cell (SOFC) planar stack is proposed to minimize the thermal gradients in the cell. This design involves including a secondary air channel with flow in the counter direction to the cathodic air channel. The effectiveness of the new design is tested by means of a tank in series reactor (TSR) model of the SOFC. It is found that the new design is capable of reducing the steady state temperature difference across the cell to less than 2 K over a range of voltages, while satisfying the requirements on fuel utilization (FU) and cell average temperature. This is achieved by manipulating the primary air channel inlet flow rate and the secondary air channel inlet temperature. More modelling and experimental studies are required to further investigate the proposed design.

13/03685 Activated carbon nanofiber anodes for microbial fuel cells

Manickam, S. S. *et al. Carbon*, 2013, 53, 19–28.

This investigation considers the use of activated carbon nanofibre non-woven (ACNFN) as a novel anode for microbial fuel cells (MFCs). ACNFN has an ultra-thin, porous interconnected structure with high bioaccessible surface area. Reduced distances from the free surface to the interior maximize use of the available surface area and this, combined with high macroporosity ensures superior performance by decreasing transport limitations. ACNFN was fabricated by pyrolysis of electrospun polyacrylonitrile and subsequent steam activation. Extensive characterization, including surface morphology, material chemistry, surface area, mechanical strength and biofilm adhesion was performed to validate the use of the material as an MFC anode. Preliminary tests in a single chamber MFC showed current densities of $2715\,A/m^3$ which is about 10% greater than the highest maximum obtained so far. Further, this was achieved with a conductivity of only a fifth of that of the corresponding material. The bio-electrochemical performance of ACNFN was also compared to that of commonly-used anodes, carbon cloth and granular activated carbon. Such anode architecture will greatly help mitigate low power density issues which are one of the main factors limiting widespread adoption of MFCs.

13/03686 Alkali production from bipolar membrane electrodialysis powered by microbial fuel cell and application for biogas upgrading

Chen, M. *et al. Applied Energy*, 2013, 103, 428–434.

Biogas upgrading is necessary for its application, and alkali CO_2 adsorption is one efficient method of achieving this. In this study, a coupled system, bipolar membrane electrodialysis (BPMED)–microbial fuel cell (MFC), was proposed for alkali production, which could also realize electricity *in situ* utilization. It was found that the pH in the alkali production chamber was 9.8. With higher NaCl concentration, bigger applied voltage and lower external resistance, the pH of the produced alkali solution also increased and the maximum value of which was 11.6. The system also performed desalination. Furthermore, the produced alkali solution was utilized for biogas upgrading. The CO_2 content decreased notably in headspace, which even reached 0% at pH 11.6 of alkali solution. This study provides an elegant and sustainable way to extend BPMED and MFC application.

13/03687 Analysis of cold start processes in proton exchange membrane fuel cell stacks

Luo, Y. *et al. Journal of Power Sources*, 2013, 224, 99–114.

To comprehensively understand the cold start processes of proton exchange membrane fuel cell (PEMFC) stack which is important for the automotive applications, a three-dimensional multiphase PEMFC stack model is developed in this study. The detailed analysis of the cold start processes shows that for the stacks with more cells, the voltage decreases more slowly due to the lower ice formation rates. The temperature increases faster for a stack with more cells, and a higher temperature can be reached at the end of the cold start process. No apparent difference in voltage exists among the different individual cells in a stack when the reactant gases are evenly supplied to each cell. The temperature in the individual cell in the middle of a stack is higher and more evenly distributed than those on the sides and single cells, due to weakened cooling effect of the bi-polar plate (BP) on the membrane electrode assembly (MEA), and the ice formation rate is also lower in the middle cell. At a lower current density, the ice in the cathode catalyst layer (CL) is formed faster at the section close to the BP, and it is close to the membrane at a higher current density.

13/03688 Calibration and uncertainty analysis for computer models – a meta-model based approach for integrated building energy simulation

Manfren, M. *et al. Applied Energy*, 2013, 103, 627–641.

This paper describes a methodology for calibration and uncertainty analysis of building simulation models applied to a monitored building case study. The practical problems to be solved were the verification and control of energy-saving measures results and the construction of a validated building simulation model for operational optimization and design optimization of further interventions. Three models were adopted for addressing the previous topics: (1) a simple piece-wise regression model trained on real data, (2) a Gaussian processes (GP) meta-model trained on computer simulation data and calibrated with respect to piece-wise regression data and (3) a detailed simulation model directly fitted to real data. The emphasis is put on the creation of the 'black-box' meta-model through GP regression technique with a radial basis function kernel, in order to establish a methodology suitable for the integrated use of multivariate real measured data and computer-based experimental data (DOE) obtained with detailed 'white box' building energy models. The methodology presented can be extended to highly multivariate input and multiple output data, enabling its application to real-time building energy analysis for continuous commissioning and event detection. In the cases in which a detailed modelling of all buildings and activities is impractical and the research for optimal solutions, according to the selected performance criteria (one or more than one), can become infeasible, data-driven models represent a possible solution. The idea of bridging the gap between data-driven and model-driven procedures and tools towards an integrated and unified approach seems to be the key point for a mature simulation based design methodology. A modelling strategy which uses a simplified physical approach, 'grey-box', is preferable to a 'black-box' one, not necessarily in terms of absolute performance (accuracy, robustness of results, etc.), but rather in terms of usability and transparency to the end-user. A reflection on a 'grey-box' approach able to address different scales and time resolutions of data with the same technique is fundamental and, in this case, more data are needed to obtain a useful reduced-order model, but the parameters can lead to a simplified physical interpretation of the underlying phenomena, increasing the confidence in the results. Adopting a Bayesian framework in stochastic processes' modelling is fundamental and although this analysis framework has been rendered more accessible in recent years (through user-friendly tools), it is necessary to recognize the effort that this technique requires. The GP technique, which assumes a Gaussian noise model in a Bayesian analysis, seems to be a good compromise between accuracy and computational cost.

13/03689 Comparison in performance of sediment microbial fuel cells according to depth of embedded anode

An, J. *et al. Bioresource Technology*, 2013, 127, 138–142.

Five rigid graphite plates were embedded in evenly divided sections of sediment, ranging from 2 cm (A1) to 10 cm (A5) below the top sediment layer. The maximum power and current of the MFCs increased in depth order; however, despite the increase in the internal resistance, the power and current density of the A5 MFC were 2.2 and 3.5 times higher, respectively, than those of the A1 MFC. In addition, the anode open circuit potentials (OCPs) of the sediment microbial fuel cells (SMFCs) became more negative with sediment depth. Based on these results, it could be then concluded that as the anode-embedding depth increases, that the anode environment is thermodynamically and kinetically favourable to anodophiles or electrophiles. Therefore, the anode-embedding depth should be considered an important parameter that determines the performance of SMFCs, and it was posited that the anode potential could be one indicator for selecting the anode-embedding depth.

13/03690 Effective diffusivity of gas diffusion layer in proton exchange membrane fuel cells

Shou, D. *et al. Journal of Power Sources*, 2013, 225, 179–186.

In gas diffusion layers (GDLs) of proton exchange membrane fuel cells (PEMFCs), effective gas diffusivity is a key parameter to be determined and engineered. Existing theoretical models of effective diffusivity are limited to one-dimensional (1D) regular fibre arrays. Numerical simulations were carried out to simulate gas diffusion through more realistic fibrous materials like GDLs, in which fibres are randomly distributed in a two-dimensional (2D) plane or three-dimensional (3D) space, but they could not fully reveal the underlying mechanisms. This paper proposes an analytical model to predict the effective diffusivities of 1D, 2D and 3D randomly distributed fibre assembles. The present model is established by extending the model of 1D regular fibre alignments to 1D random fibre arrangements through Voronoi Tessellation method, and using the 1D local diffusivities to determine the 2D and 3D diffusivities based on mixing rules. The predicted effective diffusivities agree well with experimental results and numerical data. With the new model, the influences of porosity, fibre distribution, and fibre orientation are analysed in this study.

13/03691 Effects of dimethyl ether on the performance characteristics of a direct methanol fuel cell

Seo, S. H. and Lee, C. S. *Energy Conversion and Management*, 2013, 70, 239–243.

The objective of this study was to determine the effects of dimethyl ether (DME) on the performance characteristics of a direct methanol fuel cell. Impedance and crossover experiments were performed in order to investigate the performance losses such as ohmic loss, activation loss and crossover loss accurately. The DME was pressurized to 5 bar to supply with liquid phase was and blended with an aqueous methanol solution. In this experiment, the membrane electrode assembly (MEA) was composed of Nafion 115, anode catalyst loaded Pt–Ru and cathode catalyst loaded Pt-Black. Experimental results showed that fuel cells with DME-methanol enhanced performance when compared to fuel cells with methanol only. Such performance enhancement was due to a decrease in activation losses by DME oxidation reactions. As the DME crossover through the membrane was reduced, the open circuit voltage of the fuel cell increased. Other output characteristics are also discussed.

13/03692 Enhanced power production of a membrane electrode assembly microbial fuel cell (MFC) using a cost effective poly [2,5-benzimidazole] (ABPBI) impregnated non-woven fabric filter

Choi, S. *et al. Bioresource Technology*, 2013, 128, 14–21.

A membrane electrode assembly (MEA) microbial fuel cell (MFC) with a non-woven paper fabic filter (NWF) was investigated as an alternative to a proton exchange membrane (PEM) separator. The MFC with a NWF generated a cell voltage of 545 mV and a maximum power density of 1027 mW/m^3, which was comparable to that obtained from MFCs with a PEM (551 mV, 609 mW/m^3). The MFC with a NWF showed stable cell performance (550 mV) over 300 days, whereas, the MFC with PEM performance decreased significantly from 551 to 415 mV due to biofilm formation and chemical precipitation on the membrane surface. Poly [2,5-benzimidazole] (ABPBI) was evaluated with respect to its capacity to increased proton conductivity and contact between separator and electrodes. The overall performance of the MFC with ABPBI was improved by enhancing the ion conductivity and steric contact, producing 766 mW/m^3 at optimum loading of 50 mg $ABPBI/cm^2$.

13/03693 Exergy analysis of a high-temperature-steam-driven, varied-pressure, humidification–dehumidification system coupled with reverse osmosis

Al-Sulaiman, F. A. *et al. Applied Energy*, 2013, 103, 552–561.

In this study, exergy analysis of a novel desalination system is presented and discussed. The water desalination is carried out using combined humidification–dehumidification and reverse osmosis technologies. Six system performance parameters are examined: overall exergetic efficiency, equivalent electricity consumption, specific exergy destruction, specific exergy lost, and total true specific exergy lost, as well as the exergy destruction ratios of the main components. The total true specific exergy lost is a new parameter presented in this study. It is a function of summation of total the exergy destruction rate and loss per total mass flow rate of the total pure water produced. This parameter is found to be a useful parameter to assess the exergetic performance of the system considered. By contrast, use of overall exergetic efficiency as an assessment tool can result in misleading conclusions for such a desalination system and, hence, is not recommended. Furthermore, this study reveals that the highest exergy destruction occurs in the thermal vapour compressor, which accounts for 50% of the total exergy destruction of the system considered. This study, in addition, demonstrates that the specific exergy destruction of the dehumidifier and TVC are the parameters that most strongly affect the performance of the system.

13/03694 Exfoliated graphene-supported Pt and Pt-based alloys as electrocatalysts for direct methanol fuel cells

Qian, W. *et al. Carbon*, 2013, 52, 595–604.

To greatly improve the electrocatalytic activity for methanol oxidation, high-quality exfoliated graphene decorated with uniform Pt nanocrystals (NCs) (3 nm) have been prepared by a very simple, low-cost and environmentally benign process. During the entire process, no surfactant and no halide ions were involved, which not only enabled very clean surface of Pt/graphene leading to excellent conductivity, but also greatly improved the electrocatalyst tolerance to carbon monoxide poisoning (Pt/graphene, $I_\mathrm{f}/I_\mathrm{b} = 1.197$), compared to commercial Pt/C ($I_\mathrm{f}/I_\mathrm{b} = 0.893$) catalysts. To maximize the electrocatalytic performance and minimize the amount of precious Pt, Pt–M/graphene (M = Pd, Co) hybrids have also been prepared, and these hybrids have much larger electrochemically active surface areas (ECSA), which are 4 (PtPd/graphene) and 3.3 (PtCo/graphene) times those of commercial Pt/C. The PtPd/graphene and PtCo/graphene hybrids also have remarkably increased activity toward methanol oxidation ($I_\mathrm{f}/I_\mathrm{b} = 1.218$ and 1.558). Furthermore, density functional theory (DFT) simulations demonstrate that an electronic interaction occurred between Pt atoms and graphene, indicating that graphene substrate plays a crucial role in regulating the electron structure of attached Pt atom, which confirmed that the increased efficiency of methanol oxidation was due to the synergetic effects of the hybrid structure.

13/03695 Finite element thermal stress analysis of solid oxide fuel cell cathode microstructures

Vaidya, S. and Kim, J.-H. *Journal of Power Sources*, 2013, 225, 269–276.

Two-dimensional images of solid oxide fuel cell (SOFC) cathode microstructures (50:50 wt% LSM:YSZ) are used to generate three-dimensional finite element (FE) models. An approximate, heuristic scheme is developed to derive a microstructure of 30:70 wt% LSM:YSZ composition from the original, real microstructures. The derived model is validated by calculating three-phase boundary (TPB) and phase surface area densities by comparing with data available in the literature. Construction of such derived microstructures will provide insights on the effects of phase compositions on the mechanics of electrode structures. The heuristic scheme is not proposed as a replacement for rigorous approaches such as the random packing model, but rather as a simplified approach for deriving reasonably realistic microstructures of different compositions within a limited range of validity. The models are analysed using finite elements to estimate thermal stresses and probability of failure using Weibull analysis. The effects of temperature-dependent material properties and phase volume fractions on probability of failure of the cathode are discussed.

13/03696 Investigation of a small-volume direct methanol fuel cell stack for portable applications

Yuan, Z. *et al. Energy*, 2013, 51, 462–467.

In this paper, a six-cell direct methanol fuel cell (DMFC) stack with the volume of only 13.25 cm^3 and the weight of 24.075 g is designed, fabricated and tested. First, the material characterization of the Au-coated Al current collector is investigated to exhibit superior characteristics in electric conductivity, weight and electrochemical corrosion resistance. And then the steady-state performance of the stack is tested, the maximum power output of the stack reaches 568.4 mW at room temperature. The dynamic performance and durability of the stack are also investigated in consideration of practical conditions. Results indicate that stack performance represents good responding and reproducible ability. Finally, the DMFC stack proves its good performance in powering experimental fan two times in 30 days successfully.

13/03697 Modeling and parametric simulations of solid oxide fuel cells with methane carbon dioxide reforming

Ni, M. *Energy Conversion and Management*, 2013, 70, 116–129.

A two-dimensional model is developed to simulate the performance of solid oxide fuel cells (SOFCs) fed with CO_2 and CH_4 mixture. The electrochemical oxidations of both CO and H_2 are included. Important chemical reactions are considered in the model, including methane carbon dioxide reforming (MCDR), reversible water gas shift reaction (WGSR), and methane steam reforming (MSR). It was found that at a CH_4/CO_2 molar ratio of 50/50, MCDR and reversible WGSR significantly influence the cell performance while MSR is negligibly small. The performance of SOFC fed with CO_2/CH_4 mixture is comparable to SOFC running on CH_4/H_2O mixtures. The electric output of SOFC can be enhanced by operating the cell at a low operating potential or at a high temperature. In addition, the development of an anode catalyst with high activity towards CO electrochemical oxidation is important for SOFC performance enhancement. The model can serve as a useful tool for optimization of the SOFC system running on CH_4/CO_2 mixtures.

13/03698 Overview on the developments of microbial fuel cells

Oliveira, V. B. *et al. Biochemical Engineering Journal*, 2013, 73, 53–64.

Microbial fuel cells (MFCs) are a promising technology for electricity production from a variety of materials, such as natural organic matter, complex organic waste or renewable biomass, and can be advantageously combined with applications in wastewater treatment. The problem with MFCs is that they are technically still very far from attaining acceptable levels of power output, since the performance of this type of fuel cells is affected by limitations based on irreversible reactions and processes occurring both on the anode and cathode side. However, in the last years, there has been a growing amount of work on MFCs which managed to increase power outputs by an order of magnitude. The present review article discusses a number of biological and engineering aspects related to improvement of MFC performance including the effect of important parameters, such as pH, temperature, feed rate, shear stress and organic load. The recent progresses on scale-up MFC are summarized and the different modelling approaches to describe the different biological and transport phenomena in MFCs are also provided.

13/03699 Performance assessment of molten carbonate fuel cell–humid air turbine hybrid systems

Chacartegui, R. *et al. Applied Energy*, 2013, 102, 687–699.

One of the most promising technologies for stationary power applications is the molten carbonate fuel cell (MCFC). This is due to its high efficiency, low emissions and the medium to high operating temperature. This high temperature allows for hybridization with other power generation technologies where the bottoming cycle recovers part of the heat in the fuel cell exhaust stream, hence resulting in highly efficient hybrid systems. The current MCFC hybrid system designs use microturbines as bottoming cycle. This paper presents the integration of a MCFC with a bottoming humid air turbine (HAT) instead of the conventional microturbine. The HAT cycle, even if still under development, provides a relatively simple and inexpensive solution to increase the power output of the microturbine. An indirect integration between the MCFC and the HAT cycle is chosen aiming to simplify the layout and operation of the new system and considering that the necessary modifications to be performed in the microturbine are relatively simple (and therefore the additional equipment is expected to be relatively economical). The results presented in this paper show the potential of this MCFC–HAT combination with an increase of the net power output of six percentage points and an efficiency increase of three percentage points from the high efficiency conventional hybrid system (MCFC–MGT). An economic analysis as function of the MCFC investment cost is presented showing a break-even-cost of 2092 €/kW improving the estimated for the MCFC–MGT.

13/03700 Power generation from a hybrid biological fuel cell in seawater

Strack, G. *et al. Bioresource Technology*, 2013, 128, 222–228.

A hybrid biological fuel cell (HBFC) comprised of a microbial anode for lactate oxidation and an enzymatic cathode for oxygen reduction was constructed and then tested in a marine environment. *Shewanella oneidensis* DSP-10 was cultivated in laboratory medium and then fixed on a carbon felt electrode via a silica sol–gel process in order to catalyse anodic fuel cell processes. The cathode electrocatalyst was composed of bilirubin oxidase, fixed to a carbon nanotube electrode using a heterobifunctional cross linker, and then stabilized with a silica sol–gel coating. The anode and cathode half-cells provided operating potentials of −0.44 and 0.48 V, respectively (vs Ag/AgCl). The HBFC maintained a reproducible open circuit voltage >0.7 V for 9 d in laboratory settings and sustained electrocatalytic activity for >24 h in open environment tests.

13/03701 Preparation of dense silicate electrolyte coating with low pressure plasma spraying and very low pressure plasma spraying for intermediate-temperature solid oxide fuel cells

Sun, F. *et al. Journal of Power Sources*, 2013, 223, 36–41.

Magnesium doped lanthanum silicate with apatite-type structure, as a solid electrolyte for IT-SOFC (intermediate-temperature solid oxide fuel cells), was prepared by solid state sintering. The electrolyte coatings were fabricated by low pressure plasma spraying (LPPS) and very low pressure plasma spraying (VLPPS). Their microstructures and phase composition were characterized by SEM and XRD. The gas permeability of coatings was measured with pure H_2 and O_2 at room temperature. It is shown that dense lanthanum silicate coatings can be obtained by LPPS and VLPPS. Amorphous and trace phases existed in coating deposited by LPPS. Well-crystallized lanthanum silicate coating can be prepared by one step VLPPS. The specific permeability of coating fabricated by VLPPS is $1.79 \times 10^{-19}\,m^2$.

13/03702 Relation between water adsorption in polymer-electrolyte fuel cell and its electric power

Fukada, S. *et al. Energy Conversion and Management*, 2013, 71, 126–130.

The amount of H_2O adsorbed on a Nafion® 117 membrane mounted inside a polymer-electrolyte fuel cell (PEFC) system is determined as a function of temperature and H_2O vapour pressure. Its experimental values are related with a product of electric current and terminal voltage when the anode and cathode compartments are supplied with partially moist (0–90% in relative humidity) H_2 and O_2 gases at atmospheric pressure, respectively. Under conditions of H_2O vapour pressure lower than 2×10^4 Pa, the amount of H_2O adsorbed on the membrane mounted inside the PEFC module is near to its original one that was determined under an unfixed force-free condition, where it is not mounted in cell. However, under conditions of H_2O vapour pressure higher than 2×10^4Pa, the adsorption amount under the mounted state becomes smaller than its original value determined under the unfixed force-free state. At the higher vapour pressure, the electric power generated under the mounted state also becomes lower than its value expected from the adsorption amount under the unfixed state. Thus, it is experimentally clarified that the FC power is deeply related with the amount of H_2O adsorbed on the membrane. The H_2O adsorption amount depends on whether it is compressed in a FC by an outside mould or not.

13/03703 Review: microstructured reactors for distributed and renewable production of fuels and electrical energy

Kolb, G. *Chemical Engineering and Processing: Process Intensification*, 2013, 65, 1–44.

The current paper provides an overview of recent and past research activities in the field of microreactors for energy related topics. The main research efforts in this field are currently focusing on fuel processing as hydrogen source, mostly for distributed consumption through fuel cells. Catalyst development, reactor design and testing for reforming and removal of carbon monoxide through water-gas shift, preferential oxidation, selective methanation and membrane separation are therefore under investigation. Increasing numbers of integrated complete micro fuel processors have been developed for a large variety of fuels, assisted by static and dynamic simulation of these systems. The synthesis of liquid fuels is another emerging topic, namely Fischer–Tropsch synthesis, methanol and dimethylether production from synthesis gas and biodiesel production.

13/03704 Sampling location of the inoculum is crucial in designing anodes for microbial fuel cells

Ketep, S. F. *et al. Biochemical Engineering Journal*, 2013, 73, 12–16.

A Kraft pulp mill effluent was used as the inoculum to form microbial bioanodes under controlled potential at +0.4 V/SCE. Samples were collected at the inlet and outlet of the aerated lagoon of the treatment line. The outlet sample allowed efficient bioanodes to be designed ($5.1\,A/m^2$), which included *Geobacter* and *Desulfuromonas* sp. in their microbial community. In contrast, the bioanodes formed with the inlet sample did not contain directly connecting anode-respiring bacteria and led to lower currents. It was necessary to re-form this bioanode at lower applied potential (−0.2 V/SCE) to select more efficient electroactive species and increase the current density to $5\,A/m^2$.

13/03705 Short-term effects of temperature and COD in a microbial fuel cell

Gonzalez del Campo, A. *et al. Applied Energy*, 2013, 101, 213–217.

In this work, chemical oxygen demand (COD) and temperature stress-tests on a microbial fuel cell (MFC) were studied. Regarding the temperature stress-test, its value was cyclically modified between 20 and 40 °C with stepwise increments of 5 °C. The main result was an exponentially increase in the current intensity generated. In these tests, no hysteresis was observed, indicating that the temperature stress-test did not modify the behaviour of the MFC used in this work. To study the response of the system under COD stress conditions, the influent COD concentration was stepwise modified from the steady-state value, $100\,mg\,COD\,L^{-1}$, to $3000\,mg\,COD\,L^{-1}$ and later was reduced stepwise again to $100\,mg\,COD\,L^{-1}$. In these test, it was observed that the higher the COD concentration, the higher the intensity generated. The electricity yield was an almost constant value of $6.7 \times 10^{-6}\,A\,mg^{-1}$ COD −1 COD removed per hour. In these tests, hysteresis was observed for the reverse scan, and a hysteresis loop was traced. To study how long the hysteresis lasts, several stress-tests were carried out during one week, and it was observed that the hysteresis was maintained for only 2 days. After that, the system recovered the initial behaviour.

13/03706 State of health detection for lithium ion batteries in photovoltaic system

Tsang, K. M. and Chan, W. L. *Energy Conversion and Management*, 2013, 65, 7–12.

In many photovoltaic systems, rechargeable batteries are required to even out irregularities in solar irradiation. However, the health conditions of the batteries are crucial for the reliability of the overall system. In this paper, the equivalent DC resistances of lithium ion battery cells of various health conditions during charging under different temperatures have been collected and the relationships between equivalent DC resistance, health condition and working temperature have been identified. The equivalent DC resistance can easily be obtained during the charging period of a battery by switching off the charging current periodically for a very short duration of time. A simple and effective battery charger with state of health (SOH) detection for lithium ion battery cell has been developed based on the identified equivalent DC resistance. Experimental results are included to demonstrate the effectiveness of the proposed SOH determination scheme.

13/03707 Synergetic interactions improve cobalt leaching from lithium cobalt oxide in microbial fuel cells

Huang, L. *et al. Bioresource Technology*, 2013, 128, 539–546.

Cobalt leaching from lithium cobalt oxide is a promising reduction process for recovery of cobalt and recycle of spent lithium ion batteries, but suffers from consumption of large amount of reductants and energy, and generation of excess secondary polluted sludge. Thus, effective and environmental friendly processes are needed to improve the existing process limitations. Microbial fuel cells (MFCs) effectively reduce Co(III) in lithium cobalt oxide with concomitant energy generation. There was a synergetic interaction in MFCs, leading to a more rapid Co(III) leaching at a rate 3.4 times the sum of rates by conventional chemical processes and no-acid controls. External resistor, solid/liquid ratio, solution conductivity, pH and temperature affected system performance. This study provides a new process for recovery of cobalt and recycle of spent lithium ion batteries with concomitant energy generation from MFCs.

13/03708 The effect of flow distributors on the liquid water distribution and performance of a PEM fuel cell

Jithesh, P. K. *et al. International Journal of Hydrogen Energy*, 2012, 37, (22), 17158–17171.

Water management is one of the important factors which determine the performance of a proton exchange membrane (PEM) fuel cell using hydrogen as fuel. For developing efficient water management systems, it is important to know the potential locations of formation and the nature of distribution of liquid water in the fuel cell. In the present study a PEM fuel cell with three different types of flow distributors are modelled and numerically simulated to find out the water formation and distribution characteristics. The model is validated by comparing the simulated polarization curve to experimental data. It is found that the type of flow distributor used plays a major role in determining the distribution of liquid water in the cell. A parallel flow distributor exhibits poor water removal capabilities whereas a serpentine flow distributor exhibits better water removal. A mixed flow distributor is found to give better water distribution characteristics compared to the parallel and serpentine distributors. Further the effect of liquid water formation and distribution on the species transport, temperature distribution and current generation are also investigated.

13/03709 Theoretical analysis of a glycerol reforming and high-temperature PEMFC integrated system: hydrogen production and system efficiency

Authayanun, S. *et al. Fuel*, 2013, 105, 345–352.

The aim of this study is to theoretically analyse the performance and efficiency of a glycerol processing and high-temperature proton exchange membrane fuel cell (HT-PEMFC) integrated system. Glycerol is considered a renewable fuel source for hydrogen production. In comparison with methane, glycerol shows a better performance in terms of high hydrogen production and low possibility to carbon formation. However, the content of CO_2 in the reformate gas and its dilution effect as well as the energy required for the glycerol processor should be concerned. When considering the operation of the glycerol processor for HT-PEMFCs, the reformer temperature (T_R) has a significant influence on hydrogen content in the reformate gas, whereas the steam-to-carbon ratio (S/C) affects hydrogen production slightly. In addition, the content of CO in the reformate gas satisfies the required constraint for HT-PEMFC operation. The performance and efficiency of the glycerol reforming process and HT-PEMFCs integrated system are evaluated by considering a heat recovery and a water balance.

13/03710 Transient dynamic and modeling parameter sensitivity analysis of 1D solid oxide fuel cell model

Huangfu, Y. *et al. Energy Conversion and Management*, 2013, 71, 172–185.

In this paper, a multiphysics solid oxide fuel cell (SOFC) dynamic model is developed by using a one-dimensional (1D) modelling approach. The dynamic effects of double layer capacitance on the electrochemical domain and the dynamic effect of thermal capacity on thermal domain are thoroughly considered. The 1D approach allows the model to predict the non-uniform distributions of current density, gas pressure and temperature in SOFC during its operation. The developed model has been experimentally validated, under different conditions of temperature and gas pressure. Based on the proposed model, the explicit time constant expressions for different dynamic phenomena in SOFC have been given and discussed in detail. A parameters sensitivity study has also been performed and discussed by using statistical multi-parameter sensitivity analysis method, in order to investigate the impact of parameters on the modelling accuracy.

13/03711 Use of different renewable fuels in a steam reformer integrated into a solid oxide fuel cell: theoretical analysis and performance comparison

Saebea, D. *et al. Energy*, 2013, 51, 305–313.

Hydrogen production from renewable energy resources has received significant attention with advances in fuel cell technology. The fuel type and operational reforming conditions directly affect fuel cell electricity generation. This study analyses the theoretical performance of a solid oxide fuel cell (SOFC) integrated with a steam reforming process using three different renewable fuels: ethanol, glycerol and biogas. The effects of key steam reformer operating parameters on the hydrogen production for SOFCs are investigated. The performances of SOFC systems run on different fuels are compared in terms of electrical and thermal efficiencies. It is found that the biogas-fuelled SOFC system requires the most energy, whereas the ethanol-fuelled SOFC system achieves the highest electrical and thermal efficiencies.

15 ENVIRONMENT

Pollution, health protection, applications

13/03712 A combined energy and IAQ assessment of the potential value of commissioning residential mechanical ventilation systems

Turner, W. J. *et al. Building and Environment*, 2013, 60, 194–201.

Limited data suggest that whole-house ventilation systems in California do not always perform as code and forecasts predict. Deficiencies occur because systems are usually field assembled without design specifications, and there is no consistent process to identify and correct problems. The value of such activities in terms of reducing energy use and improving indoor air quality (IAQ) is poorly understood. Commissioning such systems, either when they are installed or during subsequent building retrofits, is a step towards eliminating deficiencies and optimizing the trade-off between energy use and IAQ. The goal of this study was to determine the potential value of commissioning residential whole-house ventilation systems that are intended to comply with California's Title 24 residential ventilation requirements. A computer modelling approach was used to assess the impact on occupant health and building energy use of malfunctioning whole-house ventilation systems. Energy and IAQ impacts were quantified and then compared by using the time dependent valuation (TDV) approach for energy and a disability adjusted life year (DALY) approach for IAQ. Results showed that health benefits dominated energy benefits independently of house size and climate. The metric for commissioning whole-house ventilation systems should be net present value of the combined energy and IAQ benefits to the consumer. Commissioning cost decisions should be made relative to that value even if that means ventilating to exceed the ASHRAE 62.2 minimum. As a consequence of combining IAQ and energy costs, the beginning of an approach to optimize the ventilation rates of homes was established.

13/03713 Analysis of the energy and environmental effects of green car deployment by an integrating energy system model with a forecasting model

Lee, D. H. *et al. Applied Energy*, 2013, 103, 306–316.

By 2020, Korea has set itself the challenging target of reducing nationwide greenhouse gas emissions by 30%, more than the business-as-usual scenario, as the implementation goal required to achieve the new national development paradigm of green growth. To achieve such a target, it is necessary to diffuse innovative technologies with the capacity to drastically reduce greenhouse gas emissions. To that end, the ripple effect of diffusing innovative technologies on the energy and environment must be quantitatively analysed using an energy system analysis model such as the market allocation (MARKAL) model. However, energy system analysis models based on an optimization methodology have certain limitations in that a technology with superior cost competitiveness dominates the whole market and non-cost factors cannot be considered. Therefore, this study proposes a new methodology for overcoming problems associated with the use of MARKAL models, by interfacing with a forecasting model based on the discrete-choice model. The new methodology was applied to green car technology to verify its usefulness and to study the ripple effects of green car technology on greenhouse gas reduction. The results of this study can be used as a reference when establishing a strategy for effectively reducing greenhouse gas emissions in the transportation sector, and could be of assistance to future studies using the energy system analysis model.

13/03714 Atmospheric modeling of radioactive material dispersion and health risk in Fukushima Daiichi nuclear power plants accident

Woo, T. H. *Annals of Nuclear Energy*, 2013, 53, 197–201.

The radioactive material dispersion is investigated in terms of the radioactive concentrations. The risk of the radioactive hazard material is important with respect to the public health. The prevailing westerlies region is modelled for the dynamical consequences, whereby the Fukushima nuclear disaster in Japan is modelled. The multiplications effects of the wind values and plume concentrations are obtained. Monte Carlo calculations are performed for wind speed and direction. In Seoul and Pusan, Korea, the Cs-137 has the highest value among the chemical radioactive materials Cs-137, I-131, and Sr-90. The time for highest concentration is shown to be around 48th hour in Seoul and 12th hour in Pusan. Caesium has the highest value in both cities, and iodine has the lowest value in both cities. The wind is assumed to determine the direction of movement. Therefore, the real values are believed to be lower than the calculated results. This modelling could be used for other industrial accident cases in chemical plants.

13/03715 Determinants of electricity consumption in Dutch dwellings

Bedir, M. *et al. Energy and Buildings*, 2013, 58, 194–207.

This research aimed to define the influence of lighting and appliance use on electricity consumption in Dutch dwellings, and identify determinants of use. Data were collected via questionnaires completed by 323 dwellings in winter 2008, in the Netherlands. Three regression models were built using direct (number of lighting and appliances, duration of use) and indirect determinants (presence, dwelling-household-economic-system (DHES) characteristics); one based on the duration of appliance use and presence, one on the number of appliances and DHES characteristics, and one on the total duration of appliance use and DHES characteristics. In the first model, total duration of appliance use explained 37%, presence in rooms 14%, and combined model 37% of variance in electricity consumption. Study/hobby rooms emerged important in this model, whereas living room and kitchen did not. In the second model, number of appliances explained 21% of the variance in electricity consumption alone and 42% combined with dwelling/household characteristics. Household size, dwelling type, use of dryer, washing cycles, and number of showers appeared as significant determinants, of which the last revealing a comfort related dimension of electricity use. The third model of total duration of appliance use and dwelling/household characteristics explained 58% of the variance in electricity consumption.

13/03716 Effective quantum yield and reaction rate model for evaluation of photocatalytic degradation of water contaminants in heterogeneous pilot-scale solar photoreactors

Mueses, M. A. *et al. Chemical Engineering Journal*, 2013, 215–216, 937–947.

A generalized model for the evaluation of solar photocatalytic degradation of water pollutants in heterogeneous pilot-scale solar photoreactors using slurry suspensions of TiO_2-P25 is presented. The model is developed through the coupling of a modified rate equation derived from a Langmuir–Hinshelwood kinetic approach and a new model of 'effective' quantum yield which is based explicitly on the optical properties of the catalyst and on the incident photon flux, but independent of the composition of the reactants in solution. The model was validated experimentally in three pilot-scale, compound parabolic collectors (CPCs) of different length. The kinetic parameters obtained from this new model are intrinsic to the nature of the reagent system.

The results show that this approach is applicable to other photocatalytic degradation systems and is independent of the operating conditions, the geometry and the scale of the reactor. The model could also predict quantum yields of the photocatalytic degradation of 1,4-dioxane, hormone disrupting estrogens (E1, E2, EE2, E3), propanal, dichloroacetic acid, phenol, chlorophenols, methylphenols, 2,4-dichlorophenoxy-acetic acid (2,4-D), diuron and ametryne in single and multicomponent systems.

13/03717 Energy consumption characteristics of hotel's marketing preference for guests from regions perspective

Wang, J. C. and Huang, K.-T. *Energy*, 2013, 52, 173–184.

This research analysed how Taiwanese hotels' guest preferences from different parts of the world influence their energy consumption and the hotels' revenue. Energy consumption data, building information and hotel operation data were collected from 49 Taiwanese international tourist hotels and 24 standard tourist hotels, which are equivalent to five- and four-star hotels. The statistical results show that the energy use among hotels surveyed ranged between 83 and 408 MJ/guest per night, and could create an average revenue of US$149 for each guest. To identify a hotel's primary marketing preference for accommodating guests from a certain region, factors of certain regional guest ratios were employed. A multiple-regression model was established to characterize the hotel energy consumption via regional guest ratios. It indicates that the energy consumption varied with hotels' regional guest ratios. It also reveals that hotels with their marketing preference for accommodating guests from Europe and North America would have higher energy use characteristics followed by those aiming for guests from Australia, Asia (excluding Japan and China), Japan, domestic Taiwan, and China in descending order. Multiple regression models were used to investigate relationships between the yearly energy consumption and total revenue of hotels. The models established are statistically reliable and could be beneficial for hotels' marketing, room pricing or operating preferences. The study also reveals that guests from the developed countries generally create more revenue. However, additional energy costs will also occur, which may possibly exceed the profit. In a profit–energy costs perspective, it is recommended that targeting guests from Japan might be the most beneficial for hotels in Taiwan.

13/03718 Energy literacy, awareness, and conservation behavior of residential households

Brounen, D. *et al. Energy Economics*, 2013, 38, 42–50.

The residential sector accounts for one-fifth of global energy consumption, resulting from the requirements to heat, cool, and light residential dwellings. It is therefore not surprising that energy efficiency in the residential market has gained importance in recent years. This paper examines awareness, literacy and behaviour of households with respect to their residential energy expenditures. Using a detailed survey of 1721 Dutch households, the authors measured the extent to which consumers are aware of their energy consumption and whether they had taken measures to reduce their energy costs. The results show that 'energy literacy' and awareness among respondents is low: just 56% of the respondents are aware of their monthly charges for energy consumption, and 40% do not appropriately evaluate investment decisions in energy efficient equipment. The authors document that demographics and consumer attitudes towards energy conservation, but not energy literacy and awareness, have direct effects on behaviour regarding heating and cooling of the home. The impact of a moderating factor, measured by thermostat settings, ultimately results in strong variation in the energy consumption of private consumers.

13/03719 Energy-use in Norwegian swimming halls

Kampel, W. *et al. Energy and Buildings*, 2013, 59, 181–186.

Norway has about 850 swimming facilities with an average age of 37 years. A questionnaire issued to facility operators gave, in total, about 100 answers, and the received datasets were analysed and verified. This article contains data from a selection of 41 Norwegian swimming facilities. The final annual energy consumption (FAEC) was collected from the years 1998–2011, and all of the datasets collected were recalculated to match the Oslo climate in 2010, to make them comparable. The data shows a wide variation in FAEC. The findings are compared with corresponding Danish data, which shows a lower FAEC. Relying on the collected data and the assumptions made in this article, the potential reduction of the FAEC in Norwegian swimming pools is estimated to be around 28%.

13/03720 Environmental sustainability analysis of UK whole-wheat bioethanol and CHP systems

Martinez-Hernandez, E. *et al. Biomass and Bioenergy*, 2013, 50, 52–64.

The UK whole-wheat bioethanol and straw and distillers dried grains with solubles (DDGS)-based combined heat and power (CHP) generation systems were assessed for environmental sustainability using a range of impact categories or characterizations: cumulative primary fossil energy (CPE), land use, life cycle global warming potential over 100 years (GWP$_{100}$), acidification potential (AP), eutrophication potential (EP) and abiotic resources use (ARU). The European Union (EU) Renewable Energy Directive's target of greenhouse gas (GHG) emission saving of 60% in comparison to an equivalent fossil-based system by 2020 seems to be very challenging for stand-alone wheat bioethanol system. However, the whole-wheat integrated system, wherein the CHP from the excess straw grown in the same season and from the same land is utilized in the wheat bioethanol plant, can be demonstrated for potential sustainability improvement, achieving 85% emission reduction and 97% CPE saving compared to reference fossil systems. The net bioenergy from this system and from 172,370 ha of grade 3 land is 12.1 PJ y^{-1} providing land to energy yield of 70 GJ ha^{-1} y^{-1}. The use of distillers dried grains with solubles (DDGS) as an animal feed replacing soy meal incurs environmental emission credit, whilst its use in heat or CHP generation saves CPE. The hot spots in whole system identified under each impact category are as follows: bioethanol plant and wheat cultivation for CPE (50% and 48%), as well as for ARU (46% and 52%). EP and GWP$_{100}$ are distributed among wheat cultivation (49% and 37%), CHP plant (26% and 30%) and bioethanol plant (25%, and 33%), respectively.

13/03721 Evaluating meteorological comparability in air quality studies: classification and regression trees for primary pollutants in California's South Coast Air Basin

Choi, W. *et al. Atmospheric Environment*, 2013, 64, 150–159.

Meteorology confounds the comparison of air quality data across time and space. This presents challenges, for example, to comparisons of pollutant concentration data obtained with mobile monitoring platforms on different days and/or locations within the same airshed. In part to address this challenge, a classification and regression tree (CART) modelling approach was employed that can serve as a useful and straightforward tool in such air quality studies, to determine the comparability of meteorological conditions between measurement days and locations as well as to compare primary pollutant concentrations corrected by meteorological conditions. Specifically, regression trees were developed to obtain representative concentrations of traffic-related primary air pollutants such as NO$_x$ and CO, based on meteorological conditions for 2007–2009 in the California South Coast Air Basin (SoCAB). The resulting regression trees showed strong correlations between the regression classifications developed for different pollutant metrics, such as daily CO and NO$_x$ maxima, as well as between monitoring sites. For the SoCAB, the most important meteorological parameters controlling primary pollutant concentrations were the mean surface wind speed, geopotential heights at 925 mbar, the upper air north–south pressure gradient, the daily minimum temperature, relative humidity at 1000 mbar, and vertical stability, in approximate order of importance. The value of developing a regression tree for a single season was also explored by performing CART analysis separately on summer data. Although seasonal classifications were similar to those developed from annual data, the standard deviations of the classification groups were somewhat reduced.

13/03722 Hybrid modeling to support energy-climate policy: effects of feed-in tariffs to promote renewable energy in Portugal

Proença, S. and St. Aubyn, M. *Energy Economics*, 2013, 38, 176–185.

Feed-in tariffs have been the main policy instrument applied in Portugal for the promotion of electricity produced from renewable energy sources under the European Union Directives on energy and climate regulation. This paper provides an empirical impact assessment of the economic and environmental effects of Portugal's Feed-in tariffs policy to promote RES-E generation. Impact assessment of policy instruments plays a crucial role on decision-making process. For numerical simulations, the authors make use of a hybrid top-down/bottom-up general equilibrium modelling approach, which represents a reliable tool to analyse the complex interactions between economic, energy, and environmental issues related to energy policies. Numerical simulations confirm the empirical evidence that the Feed-in tariffs policy implemented by Portugal was both an effective and a cost-efficient way to increase the generation of electricity from renewable energy sources and thus to achieve the national RES-E target of 45% in 2010. Results show relatively modest macroeconomic impacts indicating potentially low economic adjustment costs. From an environmental perspective, the deployment of renewable energy source results in significant carbon emissions reductions.

13/03723 Impacts of occupant behaviours on residential heating consumption for detached houses in a temperate climate in the northern part of Europe

de Meester, T. *et al. Energy and Buildings*, 2013, 57, 313–323.

The occupants' behaviour has a great influence on the energy demand, management and consumption of a building. This paper investigates the influence of three parameters related to human behaviour through their modes of occupations (based on family size, management of the heating system and management of the heated area) on the housing heating loads of a standard dwelling in Belgium. Seven levels of insulation were tested: no insulation, two intermediate levels corresponding to 3 and 6 cm of insulation, the current standard for new buildings in Belgium, the low energy standard, the very low energy standard and the passive house standard. Multi-zone simulations were performed with a dynamic thermal simulation software. The impact of occupants' lifestyle and the interactions between occupation modes and insulation levels are highlighted. These results prove that the more the building is insulated, the more the lifestyle proportionally influences the heating loads. One important strategy for reducing heating consumption during the whole life cycle of the building is adapting the size of the house and its occupation modes to the evolution of family size. However, insulation is paramount, and increasing the insulation of the house provides generally better results than merely adapting the occupation mode.

13/03724 Influence of aerosols pollution on the amount of collectable solar energy

Calinoiu, D. *et al. Energy Conversion and Management*, 2013, 70, 76–82.

The paper is focused on the estimation of collectable solar energy losses in aerosol pollution events. To do this, a parametric clear sky solar irradiance model has been built and validated. For applying the model, a set of four meteorological parameters (ozone, nitrogen dioxide, water vapour column content and the Ångström turbidity coefficient) are required at input. The energy loss in a pollution episode was evaluated as the difference between the clear sky solar irradiation computed in two situations: (1) using measured values for all inputs and (2) using measured values for all inputs excepting the Ångström turbidity coefficient, for which a climatological reference value has been assumed. The calculations show that the aerosol pollution can lead to a significant loss of collectable solar energy, of over 20%. Overall results drive to the generic conclusion that the pollution episodes should be considered in both stages of a photovoltaic plant: in development, by taking them into account when the typical meteorological year is constructed, and in the exploiting stage, by accounting them in the forecasting procedure of the output power. The study was conducted with data collected in Timisoara, Romania, during 2011 and 2012.

13/03725 Influence of the cleaning additives on the methane production from brewery effluents

Rodriguez, L. *et al. Chemical Engineering Journal*, 2013, 215–216, 685–690.

Batch and continuous anaerobic tests were used to study the effect of cleaning additives on the methane production from brewery effluents. The detergents studied were based on fatty acids esters or on ethoxilated alcohols and presented EC_{50} values in *Vibrio fischeri* of 4.3 and 14.1 g/L respectively. However, these detergents were toxic to the granular sludge even at lower concentrations indicating that some of the microorganisms presented in the granular sludge were more sensitive than the *V. fischeri*. Comparing batch and continuous tests, it was observed that under continuous conditions the toxicity was lower than under batch conditions, indicating the capability of the microorganisms to get acclimatized, in the long term, to the surfactants. In the case of the detergent based on ethoxilated alcohols, the microorganisms were capable to acclimatize even at concentrations of 1000 mg/L, however in the case of the detergents based on fatty acids esters, concentrations higher than 500 mg/L caused toxicity. This toxic effect reduced the methane production significantly, reducing the energy recovery from the wastewater to about a 35% of the original value. From the results it was concluded that the detergents based on ethoxilated alcohols were more adequate than the detergent based on fatty acids esters because of its toxic effect towards granular sludge.

13/03726 Innovation under the Climate Wise program

Brouhle, K. *et al. Resource and Energy Economics*, 2013, 35, (2), 91–112.

This paper examines the impact of participation in the 'Climate Wise' programme, one of the largest voluntary programmes enacted in the USA, on innovative activity by firms. In operation from 1993 to 2000, the Climate Wise programme was designed to reduce greenhouse gas emissions by promoting innovation in energy efficiency and energy related activities. The study begins by examining what types of firms were most likely to participate in this voluntary initiative. It was found that the Climate Wise programme was attractive to large firms, more R&D intensive firms, and firms with more financial resources. To consider the impact of Climate Wise participation on the innovative behaviour of firms, the authors investigated whether participants and non-participants differed in the number of successful environmental and non-environmental patent applications between 1993 and 2003. Some evidence was found that participation in the Climate Wise leads to a change in environmental patenting but only among less R&D intensive firms.

13/03727 Isotopic evidence of enhanced carbonate dissolution at a coal mine drainage site in Allegheny County, Pennsylvania, USA

Sharma, S. *et al. Applied Geochemistry*, 2013, 29, 32–42.

Stable isotopes were used to determine the sources and fate of dissolved inorganic C (DIC) in the circumneutral pH drainage from an abandoned bituminous coal mine in western Pennsylvania. The C isotope signatures of DIC ($\delta^{13}C_{DIC}$) were intermediate between local carbonate and organic C sources, but were higher than those of contemporaneous Pennsylvanian age groundwaters in the region. This suggests a significant contribution of C enriched in ^{13}C due to enhanced carbonate dissolution associated with the release of H_2SO_4 from pyrite oxidation. The Sr isotopic signature of the drainage was similar to other regional mine waters associated with the same coal seam and reflected contributions from limestone dissolution and cation exchange with clay minerals. The relatively high $\delta^{34}S_{SO4}$ and $\delta^{18}O_{SO4}$ isotopic signatures of the mine drainage and the presence of presumptive SO_4-reducing bacteria suggest that SO_4 reduction activity also contributes C depleted in ^{13}C isotope to the total DIC pool. With distance downstream from the mine portal, C isotope signatures in the drainage increased, accompanied by decreased total DIC concentrations and increased pH. These data are consistent with H_2SO_4 dissolution of carbonate rocks, enhanced by cation exchange, and C release to the atmosphere via CO_2 outgassing.

13/03728 Land demand for ethanol production

Leal, M. R. L. V. *et al. Applied Energy*, 2013, 102, 266–271.

Several key indicators of the sustainability of biofuels are related to the land used to produce the feedstock. Most of the agronomic costs and energy use (fertilizers, herbicides, soil preparation, and harvesting) are more related to the cropped area than to the feedstock quantity produced; this is also the case of soil greenhouse gas (GHG) emissions (CO_2 and N_2O) and land use change (LUC) impacts, both direct (dLUC) and indirect (iLUC), socio-economic impacts (land tenure, land prices and traditional crop displacement), impacts on biodiversity and on the environment (soil, water and air). Today, biofuels use only a little more than 2% of the world arable land but if their use to displace fossil fuels increases, as indicated by some low carbon scenarios, the land demand for the production of feedstocks could become a constraint to the expansion. It is quite apparent that the biofuel yields, present and future, should be one of the main characteristics to be evaluated in the initial screening process. This work uses the cases of corn and sugarcane ethanol to draw some comparisons on the use of these biofuels to meet the targets of some of the International Energy Agency biofuel use scenarios in terms of land demand and also will use some of the most important study results concerning the GHG emission reduction potential, including LUC and iLUC impacts, when meeting the Renewable Energy Directive of the European Union and the Renewable Fuel Standard of the USA. Some technology improvements will be considered including the integration of first and second generation technologies in the same site processing corn or sugarcane for ethanol. The results of the simulations indicated that the land demands for the 2030 projected ethanol production in the two alternatives seems not to give reasons for concern on a global scale, but are large enough to produce significant local impacts. The GHG abatement potential is strongly dependent on the biofuel alternative considered.

13/03729 Reduction in environmental impact of sulfuric acid hydrolysis of bamboo for production of fuel ethanol

Sun, Z.-Y. *et al. Bioresource Technology*, 2013, 128, 87–93.

Fuel ethanol can be produced from bamboo by concentrated sulfuric acid hydrolysis followed by continuous ethanol fermentation. To reduce the environmental impact of this process, treatment of the stillage, reuse of the sulfuric acid and reduction of the process water used were studied. The total organic carbon (TOC) concentration of stillage decreased from 29,688 to 269 mg/l by thermophilic methane fermentation followed by aerobic treatment. Washing the solid residue from acid hydrolysis with effluent from the biological treatment increased the sugar recovery from 69.3% to 79.3%. Sulfuric acid recovered during the acid–sugar separation process was condensed and reused for hydrolysis, resulting in a sugar recovery efficiency of 76.8%, compared to 80.1% when fresh sulfuric acid was used. After acetate removal, the condensate could be reused as elution water in the acid–sugar separation process. As much as 86.3% of the process water and 77.6% of the sulfuric acid could be recycled.

13/03730 Spatio-temporal modelling of individual exposure to air pollution and its uncertainty

Gerharz, L. E. *et al. Atmospheric Environment*, 2013, 64, 56–65.

The authors developed a generic spatio-temporal model to quantify individual exposure to air pollution, using personal activity profiles derived from GPS and diaries, ambient air quality, and an indoor model. To enhance accessibility and reusability, the model approach is deployed as a web service. The model is applied to estimate personal exposure towards PM_{10} and $PM_{2.5}$ for 10 individuals in Münster, Germany. Modelled daily averages range for PM_{10} between 17 and 126 and between 6 and 84 $\mu g\,m^{-3}$ for $PM_{2.5}$. Comparison with personal monitoring data shows good agreement at temporal resolutions from 5 min to one day. Uncertainties in the model results are considerable and increase with higher exposure levels. Large deviations between modelled and measured exposure can often be explained by missing data on indoor emissions or insufficiently detailed activity diaries. The developed model allows the assessment of individual exposure with uncertainties on a high spatio-temporal resolution. By providing the methodology through a web service interface and using generic indoor parameter distributions, the model can be easily transferred to new application areas or could be provided for public use to identify hazardous exposure events.

13/03731 The determinants of household energy-saving behavior: survey and comparison in five major Asian cities

Hori, S. *et al. Energy Policy*, 2013, 52, 354–362.

It is difficult to control household energy consumption through regulation. From a policy standpoint, it is particularly challenging to identify the factors that influence people's actions. Moreover, whatever these factors are, they are unlikely to uniformly span multiple cities in the Asian region. This study conducts a survey of energy-saving behaviour to clarify the differences among such factors across five major Asian cities. The results from these surveys in Dalian, Chongqing, Fukuoka, Bangkok, and Ho Chi Minh indicate that global warming consciousness, environmental behaviour, and social interaction significantly affect energy-saving behaviour. Income and age also had weak positive effects on energy-saving behaviours. Social interaction was strongly linked to energy-saving behaviours, particularly in the rural areas of Dalian and Chongqing. This result indicates that community-based activities impact energy-saving behaviours.

13/03732 Thermodynamic analysis of EGR effects on the first and second law efficiencies of a boosted spark-ignited direct-injection gasoline engine

Li, T. *et al. Energy Conversion and Management*, 2013, 70, 130–138.

Exhaust gas recirculation (EGR) is effective to improve fuel economy of spark-ignition gasoline engines, but the detailed mechanism needs to be further investigated. In this paper, an in-depth analysis of the effects of cooled EGR on the fuel conversion efficiency of a boosted, spark-ignited, direct-injection, gasoline engines operated at the full, medium and low loads is conducted with the engine experiment and one-dimensional cycle simulation based on the first and second laws of thermodynamics. For all the operating loads, EGR increases the ratio of specific heat of working gas, reduces the fraction of heat transfer through the combustion chamber walls, and improves the pumping work during the gas exchanging stroke. Besides, EGR may replace the fuel enrichment at high load, advance the combustion phasing and increase the degree of constant volume heat release at the medium and high loads. As a result, about 1.1–4.1% improvements in the brake thermal efficiency are obtained by the 12–17% EGR at different loads. Despite the increased fraction of combustion-generated irreversibility (destruction in availability or exergy), the fraction of indicated work in the total availability increases with EGR for all the operating loads. Among the influencing factors, the effect of reduction in the heat transfer loss owing to EGR is dominant in improvement of the fuel conversion efficiency at constant air–fuel ratio, while replacement of the fuel enrichment with EGR is most effective at full load.

13/03733 Utilization of simulated flue gas for cultivation of *Scenedesmus dimorphus*

Jiang, Y. *et al. Bioresource Technology*, 2013, 128, 359–364.

Effects of flue gas components on growth of *Scenedesmus dimorphus* were investigated and two methods were carried out to eliminate the inhibitory effects of flue gas on microalgae. *S. dimorphus* could tolerate CO_2 concentrations of 10–20% and NO concentrations of 100–500 ppm, while the maximum SO_2 concentration tolerated by *S. dimorphus* was 100 ppm. Addition of $CaCO_3$ during sparging with simulated flue gas (15% CO_2, 400 ppm SO_2, 300 ppm NO, balance N_2) maintained the pH at about 7.0 and the algal cells grew well ($3.20\,g\,L^{-1}$). By intermittent sparging with flue gas controlled by pH feedback, the maximum biomass concentration and highest CO_2 utilization efficiency were $3.63\,g\,L^{-1}$ and 75.61%, respectively. These results indicated that *S. dimorphus* could tolerate high concentrations of CO_2 and NO, and the methods of $CaCO_3$ addition and intermittent sparging have great potential to overcome the inhibition of flue gas on microalgae.

13/03734 Variability and uncertainty in water demand and water footprint assessments of fresh algae cultivation based on case studies from five climatic regions

Guieysse, B. *et al. Bioresource Technology*, 2013, 128, 317–323.

Using case studies from five typical climatic locations, this study revealed that current quantification of water demand (WD) and water footprint (WF) of freshwater algae cultivation in raceway ponds suffer from uncertainty and variability in the methodologies and assumptions used. Of particular concern, the WF metric had an intrinsically poor geographical resolution and could be biased towards high-productivity arid locations because local levels of water stress are not accounted for. Applying current methodologies could therefore cause the selection of locations that are neither economically viable nor environmentally sustainable. An improved methodology should utilize more accurate evaporation models, determine realistic limits for the maximum hydraulic retention times and process water recycling ratios, and apply weighting to the WF to reflect localized water stress or use an alternative metric such as the equivalent years of rainfall required to support a productivity of $1\,GJ\,m^{-2}$.

13/03735 Water-related energy in households: a model designed to understand the current state and simulate possible measures

Kenway, S. J. *et al. Energy and Buildings*, 2013, 58, 378–389.

Energy use in households, including private transport, accounts for about 30% of primary energy use in industrialized countries. Therefore, households are important key drivers of energy use and related greenhouse gas emissions. In order to understand energy use related to water in households a detailed mathematical flow analysis of materials, energy, CO_2 emissions and costs (MMFA) for household water use was set up and tested for a specific family household in Brisbane, Australia. The simulation results for the current state of this household were well within 20% of the monitored data. After calibration, a detailed scenario investigation determined the impact of (i) potential and (ii) realistic reduction values for all relevant (a) behavioural and (b) technical parameters, including a shift from gas to a solar hot-water system. The reduction potentials for water use, greenhouse gas emissions, water-related energy consumption, water costs and water-related energy costs were 4–77%, 14–85%, 15–93%, 1–31% and 13–90% respectively. The study showed that for this household, technical improvements alone, without changing to a solar hot-water system, result in less than a 15% change in terms of energy and greenhouse gas emissions. In contrast, combined behavioural and technical changes have a much higher reduction potential.

CO_2, NO_x, SO_2 and particulate emissions

13/03736 A carbonaceous chemical filter for the selective detection of NO_2 in the environment

Dubois, M. *et al. Carbon*, 2013, 52, 17–29.

In order to achieve the selective detection of NO_2 in the environment, a chemical filter is added to a semiconductor gas sensor that is very sensitive to oxidizing gases in the gas flow. The aim is to remove ozone (O_3), the main interfering oxidizing gas for NO_2 detection before its measurement by a phthalocyanine sensor. The first parameter for the carbon material as a filter is the specific surface area (SSA), which should be high enough to ensure interaction with O_3 and low enough to avoid interaction with NO_2. The key role of surface oxygenated groups and dangling bonds was underlined by NEXAFS and EPR, respectively. A mixture of nanocones/nanodiscs (20/70% w/w) with SSA of $30\,m^2\,g^{-1}$ with both structural and electronic defects is found to be the most efficient filter and was used upstream of a phthalocyanine sensor. The lifetime of the chemical filter was investigated and a strategy to increase it is described. Raman spectroscopy, EPR and NEXAFS allow the reactivity of the carbon with NO_2 and O_3 in the 10–1000 ppb concentration range to be studied.

13/03737 A fast and accurate physics-based model for the NO_x emissions of diesel engines

Asprion, J. *et al. Applied Energy*, 2013, 103, 221–233.

To date, models for the nitrogen-oxide emissions of diesel engines are either of empirical or phenomenological nature. The former are fast and quantitatively accurate in the identified region, but lack the generality and extrapolation capability of the latter. The model presented in this work combines the advantages of both model types and thus complies with typical requirements of computationally intensive fields such as dynamic optimization and model-based control. This unique aggregation of features is achieved by extracting the most relevant physical phenomena and extending them by physically motivated empirical elements. Exploiting the assumptions made and using a setpoint-relative formulation leads to a simple model structure, comprising one map and 10 scalar parameters only. Execution speed is roughly 500 times faster than real-time and throughout the entire engine operating-range, also during transient operation, relative errors are below 10% even for the largest allowable, simultaneous variation of all inputs. Apart from engine speed and injected fuel-mass, the model requires the cylinder-charge, its composition, and the start of combustion with the corresponding pressure and temperature as inputs. The latter can either be obtained from measured in-cylinder pressure signals, or may be calculated from quantities provided by a model for the air path of the engine.

13/03738 A parametric investigation of HCCI combustion to reduce emissions and improve efficiency using a CFD model approach

Ghorbanpour, M. and Rasekhi, R. *Fuel*, 2013, 106, 157–165.

Homogeneous charge compression ignition (HCCI) combustion process is a promising method to decrease NO_x and soot emissions with low fuel consumption. In this study, a sample CI engine was simulated by a computation fluid dynamics (CFD) model through AVL Fire software. After validating the simulated results by comparing with experimental data, the compression ignition was changed into HCCI. The purpose of the study was to examine the effect of various operation variables of the HCCI engine. Firstly, the HCCI engine was simulated and the simulation results were compared to the experimental data. The comparison showed the numerical data had a good accordance with experimental data. After that, influences of various important parameters such as injection timing, air–fuel equivalence ratio, injection rate shape and exhaust gas recirculation (EGR) on HCCI combustion were analysed. The early injection can create homogeneous air and fuel mixture and advance the changing of fuel to lower hydrocarbons. Also poor and rich fuel was injected in the cylinder and their combustions were compared. It was found that the ignition timing and air–fuel equivalence ratio could control low and high temperature reactions. To have of the best combustion, fuel was injected by various injection rate shapes and it was revealed injection rate shape was effective in combustion temperature and emission quantity. Then it concentrated on the effects of cooled external exhaust gas recirculation on the combustion and pollution performance of the HCCI combustion. Cooled external EGR can delay the start of combustion (SOC) effectively, which is very useful for diesel HCCI because these fuels can be easily self-ignited and make the SOC earlier. Results showed it is possible to gain the less pollution and better performance and optimize the HCCI combustion by changing various parameters. The qualitative trends observed in the parametric variation study match well with experimental data in literature.

13/03739 Are car manufacturers on the way to reduce CO_2 emissions?: a DEA approach

Voltes-Dorta, A. *et al. Energy Economics*, 2013, 38, 77–86.

One of the pillars of the fight against climate change is reducing the amount of greenhouse gases that are emitted into the atmosphere. In that regard, curtailing CO_2 emissions from transport activities is a major objective. In its attempts of ‘decarbonizing’ transport, the European Commission set in 2009 different emission limits on the vehicles sold in Europe. With this background, this paper aims to test the ability of the major car manufacturers to meet these present and future targets with the existing technological trends. To that end, the authors provide an in-depth analysis on the temporal evolution of emission efficiencies in the Spanish car market. The well-known DEA–Malmquist method is applied over a large sample of car models sold in Spain between 2004 and 2010. A second-stage regression allows us to identify the main drivers of efficiency, catch-up and technical change over the period. Finally, the estimated trends are extrapolated to predict future emission levels for the car manufacturers. Using post-regulation rates of technical change, results show that the vast majority of companies would meet the 2015 target, 27% of the current market would meet the 2020 target, and around 3% would be able to comply with the 2025 target. Thus, since all targets are technologically feasible, stricter regulation is the recommended approach to encourage manufacturers to meet the goals set by the European Commission.

13/03740 Carbon dioxide emission from temperate semiarid steppe during the non-growing season

Chen, W. *et al. Atmospheric Environment*, 2013, 64, 141–149.

Clarifying whether grazed semiarid steppe is a sink or source of carbon dioxide (CO_2) requires accurate quantification of the annual net CO_2 exchange between the ecosystem and the atmosphere. Previous studies have primarily focused on the growing season and on single grazing pattern. Carbon dioxide emission from the temperate semiarid steppe during the non-growing season and its responses to various grazing practices still remains uncertain. Using the chamber-based technique, the authors simultaneously determined the CO_2 fluxes during the non-growing season at 12 grazed semiarid temperate steppe plots in Inner Mongolia and investigated the responses of CO_2 emission to different grazing practices. The CO_2 fluxes during the non-growing season were demonstrated to be significantly regulated by soil temperature and moisture contents. The cumulative CO_2 emission during the non-growing season (October to April) amounted to $353 \pm 26\,\mathrm{kg\,C\,ha^{-1}}$ on average (ranges: $180–484\,\mathrm{kg\,C\,ha^{-1}}$), significantly demonstrating decrease with increasing grazing intensity and increase with mean snow cover depth or mean surface soil moisture content. The empirical equations describing these significant relationships provide simple approaches to estimate the regional amounts of CO_2 emission from temperate semiarid steppe during the non-growing season.

13/03741 Control of Hg^0 re-emission from gypsum slurries by means of additives in typical wet scrubber conditions

Ochoa-González, R. *et al. Fuel*, 2013, 105, 112–118.

The effect of different additives on the re-emission of Hg^0 in wet limestone-based flue gas desulfurization (WFGD) conditions is assessed. Because re-emission of elemental mercury from limestone slurries is dependent on the pH of the gypsum slurry, re-emission of elemental mercury was evaluated for different additives using gypsum slurry with a constant pH value of 7. The additives investigated included oxidizing and reducing agents (Fenton reagents and sodium thiosulfate) and also chelating agents (2,4,6-trimercaptotriazine trisodium (TMT) and sodium hydrosulfide). Fenton reagents were added to prevent the reduction of oxidized mercury species as H_2O_2 was the precursor used to convert sulfite ions into sulfate or to oxidize Hg^0. Thiosulfate was added so that mercury could be retained in the gypsum at low concentrations as insoluble HgS, while mercury is being stabilized in the liquid fraction at higher additive doses. The addition of TMT and NaHS in low doses prevented the reduction of oxidized mercury species as insoluble HgS and Hg_3 (TMT) precipitate onto the gypsum slurry. TMT was found to be most effective additive for Hg^{2+} capture.

13/03742 Energy and environmental impact of domestic heating in Italy: evaluation of national NO_x emissions

Aste, N. *et al. Energy Policy*, 2013, 53, 353–360.

The domestic heating sector has a high potential in terms of energy savings and environmental impact. In the present study, an analysis has been carried out on the effect of domestic heating on natural gas (NG) consumption and pollutants emissions. In particular, among various emission pollutants, the nitrogen oxides (NO_x) emissions at national level were analysed in detail. The work was carried out under a collaborative research project between the Italian Ministry of the Environment and Politecnico di Milano. For the assessment of the national NO_x emissions due to residential heating, an inventory of the domestic boilers stock operating in Italy from 1999 to 2010 was made. As from a technological point of view, the precise data about the real composition of national domestic boilers stock were incomplete and not updated, a methodological procedure was developed in order to reconstruct the national domestic boilers stock based on the available technologies and thermal power. According to this scenario, the technological improvement of national boilers stock in the last decade was evaluated in terms of natural gas saving and reduced NO_x emissions. Further some discussion has been made on the energy policies for the diffusion of more efficient boilers.

13/03743 GHG emission performance of various liquid transportation biofuels in Finland in accordance with the EU sustainability criteria

Koponen, K. *et al. Applied Energy*, 2013, 102, 440–448.

The European Union (EU) has set a binding greenhouse gas (GHG) emission reduction target for transportation biofuels and other bioliquids. In this study, the GHG emissions of various biofuel chains considered as relevant in large-scale production in Finland were calculated in accordance with the EU sustainability criteria. Special attention was paid to uncertainties and the sensitivities of certain parameters. According to the results, it is impossible in many cases to unambiguously conclude whether or not a biofuel chain passes the emission-saving limit provided by the EU. This may reduce the willingness to invest in biofuel production. Major sources of uncertainties and sensitivities are nitrous oxide emissions from soil and nitrogen fertilization, emissions of process heat production and soil carbon stock changes in biomass production. Several propositions are made in order to reduce the uncertainty of the results and to make the EU sustainability criteria for biofuels more harmonized and accurate.

13/03744 H_2S emissions from Cerro Prieto geothermal power plant, Mexico, and air pollutants measurements in the area

Peralta, O. *et al. Geothermics*, 2013, 46, 55–65.

This study measured the meteorological parameters and environmental concentrations of hydrogen sulfide (H_2S) and criteria pollutants at Cerro Prieto, Mexico, from May to July 2010. In addition, non-condensable gases from vent stacks at Cerro Prieto geothermal power plant were sampled and analysed by gas chromatography–mass spectrometry. A dispersion model, which was validated with environmental measurements, was applied to H_2S. Criteria pollutants never exceeded the Mexican air quality standards. Results from dispersion modelling were compared against measured concentrations showing acceptable agreements for Chi square goodness of fit (χ^2) in the 95% significance level ($\alpha = 0.05$), at afternoons and evening events when boundary layer is decreasing and wind speed is less than 5.5 m s^{-1}. Determination coefficient of curve fitting for computed concentrations at less than 4 km from the source was 0.513 and farther 0.568. This study was the first to measure criteria pollutants and H_2S in Cerro Prieto area.

13/03745 Inventory of conventional air pollutants emissions from road transportation for the state of Rio de Janeiro

de Souza, C. D. R. *et al. Energy Policy*, 2013, 53, 125–135.
Road transportation has contributed to increased emissions of conventional air pollutants and, consequently, to the increase in problems associated with the environment and human health, depending on the type of pollutant and the concentration of it. To support the development of public policies aimed to decrease total tonnes of emissions, the authors used a bottom-up approach to estimate the amount of air pollutants, such as carbon monoxide (CO), total hydrocarbons (THC), nitrogen oxides (NO_x), particulate matter (PM), and aldehydes (RCHO), that are emitted by road transportation in the state of Rio de Janeiro (RJ) from 1980 to 2010. The results from 2010 show that cars are responsible for 55% of CO emissions, 61% of THC emissions, and 93% of RCHO emissions. Due to the use of hydrated ethanol and compressed natural gas (CNG) instead of petroleum based fuels during the period analysed, 1,760,370 t of air pollutant emissions were avoided. Compared to Brazil, in 2010, RJ had a quantity of emissions per vehicle from 12% (CO) to 59% (PM) smaller than the national average. As strategies to reduce air pollutant emissions, the authors consider reducing the intensity of use, with a proportional reduction in emissions, and increased the use of biodiesel.

13/03746 Laboratory experiments and field study for the detection and monitoring of potential seepage from CO_2 storage sites

Caramanna, G. *et al. Applied Geochemistry*, 2013, 30, 105–113.
Potential CO_2 seepages from geological storage sites or from the injection rig may affect the surrounding environment. To develop reliable detection techniques for such seepages a laboratory rig was designed that is composed of three vertical Plexiglas columns. The columns can be filled with sediments and water; CO_2 can be injected from the bottom. Two columns are used to simulate the impact of CO_2 on soils; while the third one, which is larger in size, simulates CO_2 seepage in aquatic environments. The main results of the laboratory experiments indicate that increased levels of CO_2 generate a quick drop in pH. Once the seepage is stopped, a partial recovery towards the initial values of pH is recorded. The outcomes of the laboratory experiments on the aquatic seepage are compared with observations from a submarine natural emission of CO_2. In this natural underwater seepage multi-parametric probes and laboratory analysis were used to analyse the composition and the chemical effects of the emitted gas; basic acoustic techniques were tested as tools for the prompt detection of CO_2 bubbles in water.

13/03747 Optimization of carbon dioxide capture and storage with mineralisation using recyclable ammonium salts

Wang, X. and Maroto-Valer, M. M. *Energy*, 2013, 51, 431–438.
Optimization of carbon dioxide capture and storage with mineralization (CCSM) using recyclable ammonium salts (RAS) was studied here in order to minimize the energy consumption of this process. Water evaporation is required for the recycling of ammonium salts in the process, however the water evaporation technologies normally impose high energy penalty. In the optimized process, solid to liquid (S/L) ratio was increased to reduce water usage, but this change impacts dissolution efficiency, where the dissolution efficiency decreased from 100% at S/L of 50 g/l to 71% at S/L of 300 g/l. However, a 6% increase of dissolution efficiency was reported when the S/L ratio increased from 200 to 300 g/l, probably due to increasing mineral intercollisions. Besides, the optimized process employed the pressurized reactor, this change resulted in the mineral phase of product changed from hydromagnesite to magnesite. The carbon fixation efficiency was significantly improved by using $(NH_4)_2CO_3$ compared to NH_4HCO_3, and the highest CO_2 fixation efficiency achieved was 46.6% at S/L of 300 g/l. The mass balance for the optimized process was 4.9 t of serpentine, 0.6 t of NH_4HSO_4, 4.7 t of $(NH_4)_2CO_3$ and 16 t of water required to sequester 1 t CO_2.

13/03748 Pd-based composite membrane and its high-pressure module for pre-combustion CO_2 capture

Ryi, S.-K. *et al. Energy*, 2013, 51, 237–242.
This study investigates configuration of a module for withstanding high pressure and temperature for CO_2 capture from a coal gasifier. In order to increase the durability of the module at high pressure and temperature, a flange-type unit-cell module was installed in a high-pressure chamber. Hydrogen permeation and N_2 leakage tests showed that H_2/N_2 selectivity remained at ~4000 after ~300 h at a pressure difference of 2000 kPa (~20 bar) and 673 K. A CO_2 capturing test was carried out at 673 K and a pressure difference of 2000 kPa with a 40% CO_2 + 60% H_2 feed gas mixture, which is similar to the composition in a coal gasifier after shift reaction and H_2O removal. It was shown that CO_2 could be enriched up to 78–95% with a hydrogen recovery ratio of 82–97% when the feed flow rate was 0.05–0.17 N m^3 h^{-1} with a membrane surface area of 16. 6 cm^2.

13/03749 Predictive modeling of CO_2 sequestration in deep saline sandstone reservoirs: impacts of geochemical kinetics

Balashov, V. N. *et al. Applied Geochemistry*, 2013, 30, 41–56.
One idea for mitigating the increase in fossil-fuel generated CO_2 in the atmosphere is to inject CO_2 into subsurface saline sandstone reservoirs. To decide whether to try such sequestration at a globally significant scale will require the ability to predict the fate of injected CO_2. Thus, models are needed to predict the rates and extents of subsurface rock–water–gas interactions. Several reactive transport models for CO_2 sequestration created in the last decade predicted sequestration in sandstone reservoirs of ~17 to ~90 kg CO_2 m^{-3}. To build confidence in such models, a baseline problem including rock + water chemistry is proposed as the basis for future modelling so that both the models and the parameterizations can be compared systematically. In addition, a reactive diffusion model is used to investigate the fate of injected supercritical CO_2 fluid in the proposed baseline reservoir + brine system. In the baseline problem, injected CO_2 is redistributed from the supercritical (SC) free phase by dissolution into pore brine and by formation of carbonates in the sandstone. The numerical transport model incorporates a full kinetic description of mineral–water reactions under the assumption that transport is by diffusion only. Sensitivity tests were also run to understand which mineral kinetics reactions are important for CO_2 trapping. The diffusion transport model shows that for the first ~20 years after CO_2 diffusion initiates, CO_2 is mostly consumed by dissolution into the brine to form $CO_{2,aq}$ (solubility trapping). From 20 to 200 years, both solubility and mineral trapping are important as calcite precipitation is driven by dissolution of oligoclase. From 200 to 1000 years, mineral trapping is the most important sequestration mechanism, as smectite dissolves and calcite precipitates. Beyond 2000 years most trapping is due to formation of aqueous HCO_3^-. Ninety-seven per cent of the maximum CO_2 sequestration, 34.5 kg CO_2 per m^3 of sandstone, is attained by 4000 years even though the system does not achieve chemical equilibrium until ~25,000 years. This maximum represents about 20% CO_2 dissolved as $CO_{2,aq}$, 50% dissolved as $HCO^{-}{}_{3,aq}$, and 30% precipitated as calcite. The extent of sequestration as $HCO^{-}{}_{3}$ at equilibrium can be calculated from equilibrium thermodynamics and is roughly equivalent to the amount of Na^+ in the initial sandstone in a soluble mineral (here, oligoclase). Similarly, the extent of trapping in calcite is determined by the amount of Ca^{2+} in the initial oligoclase and smectite. Sensitivity analyses show that the rate of CO_2 sequestration is sensitive to the mineral–water reaction kinetic constants between approximately 10 and 4000 years. The sensitivity of CO_2 sequestration to the rate constants decreases in magnitude respectively from oligoclase to albite to smectite.

13/03750 Reducing the CO_2 emissions in Croatian cement industry

Mikulčić, H. *et al. Applied Energy*, 2013, 101, 41–48.
The cement industry is one of the largest carbon-emitting industrial sectors. It is responsible for about 5% of anthropogenic CO_2 in the world. Therefore, it is a relevant industrial sector for CO_2 emission regulation strategies. Bearing in mind the importance of cement industry in Croatia, and because of the fact that Croatia will soon become a European Union (EU) member state, the present paper analyses the potential to reduce CO_2 emission in the Croatian cement industry. There are several measures that can reduce CO_2 emissions from the cement manufacturing process: the use of waste heat as an alternative source of energy; CO_2 capture and storage technologies; reduction of clinker to cement ratio; the use of alternative and biomass fuels; the use of alternative raw materials; an energy efficient combustion process. The most energy efficient technology for cement manufacturing today is the use of a rotary kiln together with a multi-stage preheater and a calciner. Since the use of cement calciners is a relatively new technology, further improvement of their operating conditions is still needed. This paper also highlights the results of research in the field of computational fluid dynamic simulations that are used for the investigation of process and combustion emissions. The above mentioned measures together with numerical investigations can reduce the effect of cement manufacturing in Croatia on the environment and can make it more competitive with cement manufacturers from the EU.

13/03751 Structural decomposition analysis of the carbonization process in Beijing: a regional explanation of rapid increasing carbon dioxide emission in China

Tian, X. *et al. Energy Policy*, 2013, 53, 279–286.

Methods to control China's CO_2 emissions under its rapid economic development process have received much attention. As the top industrialized and urbanized region in China, Beijing is a good case to show the trends of CO_2 emissions in China, and examining how different drivers influence the CO_2 emissions direction of Beijing can give valuable insights to other regions on dealing with the emerging climate change issues. To this end, the authors conducted structural decomposition analysis to quantify the contributions of technological and socio-economic factors to the rapid CO_2 emissions growth in Beijing from 1995 to 2007. An increasing final demand level and production structure change led to carbonizing Beijing significantly, while energy intensity improvement was Beijing's sole prominent source on decarbonizing its economic development in 1995–2007. Further, results highlighted the importance of trading and investment in CO_2 emissions variations in Beijing. The industrial structure change toward heavy manufacturing and services sectors led to the significant role of these sectors in CO_2 emissions growth in Beijing. Beijing's carbonizing process is a reminder to other regions in China to reconsider the direction of their industrial structure change and implement consistent and strict energy-saving policies.

Hydrocarbon emissions

13/03752 Coal induced production of a rhamnolipid biosurfactant by *Pseudomonas stutzeri*, isolated from the formation water of Jharia coalbed

Singh, D. N. and Tripathi, A. K. *Bioresource Technology*, 2013, 128, 215–221.

A strain of *Pseudomonas stutzeri* was isolated from an enrichment of perchlorate reducing bacteria from the formation water collected from an Indian coalbed which solubilized coal and produced copious amount of biosurfactant when coal was added to the medium. It produced maximum biosurfactant with lignite coal followed by olive oil and soybean oil which was able to emulsify several aromatic hydrocarbons including kerosene oil, diesel oil, hexane, toluene, etc. Haemolytic test, growth inhibition of *Bacillus subtilis* and FTIR analysis showed rhamnolipid nature of the biosurfactant. The stability of the coal induced biosurfactant in pH range of 4–8 and up to 25% NaCl concentration and 100 °C temperature suggests that due to its ability to produce biosurfactant and solubilize coal *P. stutzeri* may be useful in the coalbed for *in situ* biotransformation of coal into methane and in the bioremediation of PAHs from oil contaminated sites including marine environments.

13/03753 Estimating the social cost of non-CO_2 GHG emissions: methane and nitrous oxide

Marten, A. L. and Newbold, S. C. *Energy Policy*, 2012, 51, 957–972.

Many estimates of the social cost of CO_2 emissions ($SCCO_2$) can be found in the climate economics literature. However, to date few estimates of the social costs of other greenhouse gases have been published, and most are not comparable to current estimates of the $SCCO_2$. This study constructs an integrated assessment model that combines a climate model, MAGICC, and economic components from DICE to estimate the social costs of CO_2, CH_4, and N_2O for the years 2010–2050, using assumptions similar to the recent US government interagency SCC working group. The authors compare their estimates of the social costs for non-CO_2 gases to those produced using the $SCCO_2$ to value 'CO_2-equivalent' emissions, calculated using global warming potentials (GWPs). They examine the estimation error associated with using GWPs for single- and multi-gas abatement policies. In both cases the error can be large, so estimates of the social costs of these gases should be used whenever possible. However, if direct estimates are not available the value of reductions estimated using GWPs will typically have lower absolute errors than default estimates of zero, and provide lower bounds of the abatement benefits.

13/03754 Quantitative analysis of polycyclic aromatic hydrocarbons in solid residues from supercritical water gasification of wet sewage sludge

Xu, Z. R. *et al. Applied Energy*, 2013, 102, 476–483.

Hydrogen gas has been successfully produced from sewage sludge by supercritical water gasification. Therefore, whether toxic compounds are synthesized in the supercritical water gasification of sewage sludge should be clarified because of the complex pollutants in sludge. In the current study, the content and forms of polycyclic aromatic hydrocarbons (PAHs) in the solid residue from the supercritical water gasification of wet sludge was investigated using a high-pressure autoclave. The process parameters, such as reaction temperature (400–455 °C), reaction time (0–60 min), dry matter content (5.6–23.8 wt%) in the feedstock, and heating period, were varied to investigate their effects on the PAH content and forms. The results showed that PAHs are generated during supercritical water gasification and that high reaction temperature, long reaction time, and low dry matter content favour the formation of PAHs in the solid residue, mainly involving four-ring PAHs. Moreover, the amount of total PAHs in the solid residue did not exceed the allowable limits of soil quality assessment for exhibition (B class) in China and meets the Canadian soil quality for commercial land use. In addition, the mechanism of PAH formation during supercritical water gasification was discussed in this paper.

13/03755 VOC emissions of smouldering combustion from Mediterranean wildfires in central Portugal

Evtyugina, M. *et al. Atmospheric Environment*, 2013, 64, 339–348.

Emissions of trace gases and C_5–C_{10} volatile organic compounds (VOCs) from Mediterranean wildfires occurring in Portugal in summer 2010 were studied. Fire smoke was collected in Tedlar bags and analysed for CO, CO_2, total hydrocarbons (THC) and VOCs. The CO, CO_2 and THC emission factors (EFs) were 206 ± 79, 1377 ± 142 and $8.1 \pm 9\,g\,kg^{-1}$ biomass burned (dry basis), respectively. VOC emissions from Mediterranean wildfires were reported for the first time. Aromatic hydrocarbons were major components of the identified VOC emissions. Among them, benzene and toluene were dominant compounds with EFs averaging 0.747 ± 0.303 and $0.567 \pm 0.422\,g\,kg^{-1}$ biomass burned (dry basis), respectively. Considerable amounts of oxygenated organic volatile compounds (OVOCs) and isoprenoids were detected. 2-Furaldehyde and hexanal were the most abundant measured OVOCs with EFs of 0.337 ± 0.259 and $0.088 \pm 0.039\,g\,kg^{-1}$ biomass burned (dry basis), respectively. The isoprenoid emissions were dominated by isoprene ($EF = 0.207 \pm 0.195\,g\,kg^{-1}$ dry biomass burned) and α-pinene ($EF = 0.112 \pm 0.093\,g\,kg^{-1}$ dry biomass burned). Emission data obtained in this work are useful for validating and improving emission inventories, as well for carrying out modelling studies to assess the effects of vegetation fires on air pollution and tropospheric chemistry.

Life cycle analysis

13/03756 A life cycle energy analysis of social housing in Brazil: case study for the program 'My House My Life'

Paulsen, J. S. and Sposto, R. M. *Energy and Buildings*, 2013, 57, 95–102.

The Brazilian government has started up a large social housing program for low-income families. Considering the large investment for this program, it is important to analyse the environmental impact to create a base for further improvement assessment. The goal of this paper is to visualize the energy use (embodied and operational) during the life cycle of case study for a house in the social housing program. The case study showed that the embodied energy is $7.2\,GJ/m^2$ or 30% of the total energy from the life cycle, the operational energy is $17.5\,GJ/m^2$. Half of the embodied energy is due to material use for maintenance and around 57% of the embodied energy is used in the wall construction. Compared to other international studies ($5.8\,GJ/m^2$ per 50 years), the embodied energy is relative high ($7.2\,GJ/m^2$ per 50 years) whereas the operational energy is only the half (17.5 compared to $36\,GJ/m^2$ per 50 year). The study indicates that the largest improvement potential for reducing the embodied energy is connected to the walls trough choosing materials and systems with less embodied energy and higher durability to decrease the need for maintenance and substitution of materials.

13/03757 Application of life-cycle assessment to early stage building design for reduced embodied environmental impacts

Basbagill, J. *et al. Building and Environment*, 2013, 60, 81–92.

Decisions made during a building's early design stages critically determine its environmental impact. However, designers are faced with many decisions during these stages and typically lack intuition on which decisions are most significant to a building's impact. As a result, designers often defer decisions to later stages of the design process. Life-cycle assessment (LCA) can be used to enable better early stage decision-making by providing feedback on the environmental impacts of building information modelling (BIM) design choices. This paper presents a method for applying LCA to early stage decision-making in order to inform designers of the relative environmental impact importance of building component material and dimensioning choices. Sensitivity analysis is used to generalize the method across a range of building shapes and design parameters. An impact allocation scheme is developed that shows the distribution of embodied impacts among building elements, and an impact reduction scheme shows which material and thickness decisions achieve the greatest embodied impact reductions. A multi-building residential development is used as a case study for introducing the proposed method to industry practice. Results show that the method can assist in the building design process by highlighting those early stage decisions that frequently achieve the most significant reductions in embodied carbon footprint.

13/03758 End-of-life of starch–polyvinyl alcohol biopolymers

Guo, M. *et al. Bioresource Technology*, 2013, 127, 256–266.

This study presents a life cycle assessment (LCA) model comparing the waste management options for starch–polyvinyl alcohol (PVOH) biopolymers including landfill, anaerobic digestion (AD), industrial composting and home composting. The ranking of biological treatment routes for starch–PVOH biopolymer wastes depended on their chemical compositions. AD represents the optimum choice for starch–PVOH biopolymer containing N and S elements in global warming potential (GWP_{100}), acidification and eutrophication but not on the remaining impact categories, where home composting was shown to be a better option due to its low energy and resource inputs. For those starch–PVOH biopolymers with zero N and S contents home composting delivered the best environmental performance amongst biological treatment routes in most impact categories (except for GWP_{100}). The landfill scenario performed generally well due largely to the 100-year time horizon and efficient energy recovery system modelled but this good performance is highly sensitive to assumptions adopted in landfill model.

13/03759 Environmental evaluation of power transmission in Norway

Jorge, R. S. and Hertwich, E. G. *Applied Energy*, 2013, 101, 513–520.

Electrical grid systems are required as a consequence of energy not being produced in the same place as it is consumed, and they are a key element of energy systems. Transmission and distribution assets comprised of power lines, cables, transformers, substations and other electrical equipment generate a wide range of environmental impacts. Throughout the lifetime of the equipment, the impacts originate mainly from power losses during the use phase, but other life cycle stages such as installation, maintenance and dismantling also contribute significantly to some impact categories. In this paper, the environmental impacts of the Norwegian transmission grid are assessed. The methodology used here is life cycle assessment (LCA) with ReCiPe as impact assessment method. In total, 11,097 km of lines and cables, 345 transformers and 121 substations were installed in the Norwegian transmission grid by the end of 2009; the network also included some hundreds of kilometres of sea cables between Norway and abroad. The results show that for each kW h of electricity transmitted in Norway, climate change impacts are of 1.3–1.5 g CO_2 eq., assuming a Norwegian electricity mix. Half of these emissions are associated with power losses, and the other half with infrastructure processes such as materials production, installation, maintenance and end of life. The results also show that after the losses, the infrastructure processes for overhead lines and transformers, and the emissions of SF_6 from gas-insulated equipment are the most relevant contributors for total climate impacts. A sensitivity analysis is done with respect to the electricity mix used to model power losses in the system. The results show that the contribution of power losses to the total climate change scores increases to 84% and 94%, by replacing the Norwegian mix by the Nordic mix and the European mix, respectively.

13/03760 Identification of the environmental impact from the use of different materials in domestic solar hot water systems

Martinopoulos, G. *et al. Applied Energy*, 2013, 102, 545–555.

The use of different materials for the same solar system component (collector, water tank, etc.) affects both the efficiency and the amount of conventional energy substituted by the system and hence the overall environmental impact of a domestic solar hot water system (DSHWS). The net environmental gain achieved by the use of DSHWS therefore is influenced, among others, by the materials and techniques used, up to 20% in some cases. In this paper, life cycle analysis of a variety of typical, for the Greek market, DSHWS is performed. Their environmental impact, as well as the influence from the use of different materials or/and manufacturing techniques on their impact, is identified. In all cases examined, the environmental impact of the solar systems is significantly lower compared to that of the energy conserved. As thermal efficiency differs from system to system, their environmental performance is influenced mainly by the conventional energy substituted and to a lesser extent by the materials used for their production.

13/03761 Life cycle assessment of alveolar brick construction system incorporating phase change materials (PCMs)

Castell, A. *et al. Applied Energy*, 2013, 101, 600–608.

An evaluation of the environmental impact of construction systems that are composed of facades based on alveolar bricks and macroencapsulated phase change materials (PCM) done using life cycle assessment (LCA) is presented. Their energy consumption rates for both heating and cooling have been measured and registered in two experimental cubicles located in Puigverd de Lleida in Spain. This work examines if the reduction of the environmental impact that is reached due to the energy savings achieved during the operational phase of these cubicles compensates the increase of the environmental impact that is induced during the manufacturing phase. Theoretical case studies, such as assuming different climatization and weather conditions, are proposed and studied to determine the most suitable climatic conditions for using the alveolar bricks and PCM technologies. Within the context of the LCA study, it is concluded that the overall benefit of PCM is the highest when summer weather conditions throughout the whole year is theoretically assumed, where for different assumed lifetime periods of the cubicles the reduction of the overall global impact of the cubicle containing PCM ranges from 12% to 14% in comparison to the other cubicle without PCM.

13/03762 Life cycle assessment of two emerging sewage sludge-to-energy systems: evaluating energy and greenhouse gas emissions implications

Cao, Y. and Pawlowski, A. *Bioresource Technology*, 2013, 127, 81–91.

A 'cradle-to-grave' life cycle assessment was conducted to examine the energy and greenhouse gas (GHG) emission footprints of two emerging sludge-to-energy systems. One system employs a combination of anaerobic digestion (AD) and fast pyrolysis for bioenergy conversion, while the other excludes AD. Each system was divided into five process phases: plant construction, sludge pretreatment, sludge-to-bioenergy conversion, bioenergy utilizations and biochar management. Both systems achieved energy and GHG emission benefits, and the AD-involving system performed better than the AD-excluding system (5.30 vs 0.63 GJ/t sludge in net energy gain and 0.63 vs 0.47 t CO_2eq/t sludge in emission credit for base case). Detailed contribution and sensitivity analyses were conducted to identify how and to what degree the different life-cycle phases are responsible for the energy and emission impacts. The energy and emission performances were significantly affected by variations in bioenergy production, energy requirement for sludge drying and end use of bioenergy.

13/03763 Life cycle assessment integrated with thermodynamic analysis of bio-fuel options for solid oxide fuel cells

Lin, J. *et al. Bioresource Technology*, 2013, 128, 495–504.

A methodology that integrates life cycle assessment (LCA) with thermodynamic analysis is developed and applied to evaluate the environmental impacts of producing biofuels from waste biomass, including biodiesel from waste cooking oil, ethanol from corn stover, and compressed natural gas from municipal solid wastes. Solid oxide fuel cell-based auxiliary power units using bio-fuel as the hydrogen precursor enable generation of auxiliary electricity for idling heavy-duty trucks. Thermodynamic analysis is applied to evaluate the fuel conversion efficiency and determine the amount of fuel feedstock needed to generate a unit of electrical power. These inputs feed into an LCA that compares energy consumption and greenhouse gas emissions of different fuel pathways. Results show that compressed natural gas from municipal solid wastes is an optimal bio-fuel option for SOFC-APU applications in New York state. However, this methodology can be regionalized within the USA or internationally to account for different fuel feedstock options.

13/03764 Life cycle CO_2 assessment method for concrete using CO_2 balance and suggestion to decrease $LCCO_2$ of concrete in South-Korean apartment

Lee, S. *et al. Energy and Buildings*, 2013, 58, 93–102.

This study investigates a sustainable development method such as material, service life and reuse of concrete in terms of CO_2 balance (emission–absorption) and $LCCO_2$ (life cycle CO_2) of concrete to suppress the reckless development in pursuit of economic profits in the construction industry of Korea. The CO_2 balance and $LCCO_2$ for the real apartment were evaluated by calculating the CO_2 emission from concrete use and CO_2 absorption from concrete carbonation during the service life of building as a case study. Service lives of 20, 40, 60, 80 and 100 years of a building were calculated and compared. Based on the result of this study, the need for a sustainable development strategies such as (1) building service life expansion, (2) an increase in use of blended cement in concrete and (3) waste concrete reuse obligation as a recycled aggregate or a roadbed material, was proposed to facilitate sustainable development in the construction industry of South Korea.

13/03765 Life-cycle fossil energy consumption and greenhouse gas emission intensity of dominant secondary energy pathways of China in 2010

Li, X. *et al. Energy*, 2013, 50, 15–23.

Life-cycle fossil primary energy consumption (FPEC) and greenhouse gas (GHG) emission intensity of nine types of dominant secondary energy (SE) pathways for China in 2010 are calculated with iterative methods, using the TLCAM (Tsinghua Life-cycle Analysis Model). Three major types of GHG (CO_2, CH_4 and N_2O) are considered for GHG emission intensity, and non-combustion CH_4 leakage during the feedstock production sub-stage is included. The authors found the following results. (1) life-cycle FPEC intensities in units of per MJ SE are obtained and used, in order of magnitude, for: raw coal (recovered only); raw natural gas (NG, recovered and processed only); raw oil (recovered and processed); final coal (finally transported to end-user); final NG (finally transported to end-user); diesel; gasoline; residual oil and electricity. (2) Although their upstream GHG emission intensities are small, their life-cycle intensities are 103.5, 68.3, 81.6, 99.3, 70.0, 101.6, 91.7, 93.5 and 226.4 g $CO_{2,e}$/MJ SE, respectively, when direct GHG emissions are included. (3) Life-cycle intensities of both FPEC and GHG emissions for SE in China are higher than those in some other countries, because of the relatively low overall efficiency and high percentage of coal in the national energy mix.

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Supplies, policy, economics, forecasts

13/03766 A simplified method to predict hourly building cooling load for urban energy planning

Duanmu, L. *et al. Energy and Buildings*, 2013, 58, 281–291.

It is not feasible to apply the traditional prediction method to predict hourly building cooling load at the urban energy planning stage because of the limited building information and complexity of energy prediction. This paper presents a simplified prediction model: hourly cooling load factor method that can provide quick and fair estimate of building cooling load for large-scale urban energy planning. The paper introduces the assumptions and principles of the proposed method, as well as discussing the implication and limitation of the approach. As a verification and demonstration, the method is applied to an office building in Beijing. The predicted results show that the dynamical trend of the cooling load is reasonable. The study further analyses the potential causes of prediction errors and the significance of various cooling load influence factors.

13/03767 A universal climate-based energy and thermal expectation index: initial development and tests

Emmanuel, R. *et al. Energy and Buildings*, 2013, 58, 208–218.

This study protoyped a set of energy indices that can be used to assess, classify and compare any worldwide climate (weather data or extrapolated climate change data) to understand its energy burden on buildings and for the use in sustainable building design. The indices are intended as rapid and interactive holistic design tools applicable to any building type, with any design strategy, in any location worldwide and for the simple quantification of the impact of climate change on building energy use over its lifecycle. The indices are based on the fact that climate underlies building energy use and it is therefore possible to compare designs relative to climate, visualize where design emphasis needs to be placed and directly and interactively track the effect of design strategies. They were then tested against the well-known Mahoney's table as well as against other parametric simulation software to evaluate their robustness and applicability in a wide variety of climatic contexts from around the world. The index works well in most climates except hot, humid ones. Lessons for future development and implementation are discussed.

13/03768 An explanation of residential energy-efficiency retrofit behavior in Canada

Gamtessa, S. F. *Energy and Buildings*, 2013, 57, 155–164.

In 1998 the Canadian government introduced the EnerGuide for Houses (EGH) program, essentially consisting of home energy audits with financial incentives provided to the homeowner on verification that sufficient auditor-recommended upgrades were undertaken to achieve energy savings. This study analyses the EGH data compiled between October 1998 and September 2005 to determine what types of households chose to participate and what appear to be the main factors underlying retrofit decisions. In the program, homeowners were prescribed specific upgrade types in the first audit. Hence, the decision problem involves whether to retrofit at all and how many of the prescribed upgrades to adopt. Moreover, the second audit that reveals this decision does not reflect the possibility that some homeowners might have undertaken the recommended upgrades but opted not to or have yet to undergo the second audit. The study adopts an econometric technique that takes these features of the data into account. It was found that energy cost savings, financial incentives, and costs of retrofits are important factors behind retrofit decisions given several other home- and household-specific characteristics.

13/03769 Are fluctuations in US production of renewable energy permanent or transitory?

Lean, H. H. and Smyth, R. *Applied Energy*, 2013, 101, 483–488.

This study examines the integration properties of total renewable energy production, as well as production of biofuels and biomass in the USA. To do so, Lagrange multiplier univariate unit root tests with up to two structural breaks are used. It is concluded that each production series has a unit root. The result suggested that random shocks, encompassing changes to regulation, to renewable energy production may lead to permanent departures from predetermined target levels. Furthermore, this result implied that permanent positive shocks (such as renewable portfolio standards) that increase the production of renewable energy resources will realize more in terms of positively altering the energy mix between renewable energy and energy from fossil fuels than temporary policy stances (such as investment tax credits over a predetermined time horizon).

13/03770 Evaluating future scenarios for the power generation sector using a multi-criteria decision analysis (MCDA) tool: the Portuguese case

Ribeiro, F. *et al. Energy*, 2013, 52, 126–136.

A multi-criteria decision analysis (MCDA) tool was designed and used to support the evaluation of different electricity production scenarios. The MCDA tool is implemented in a user-friendly Excel worksheet and uses information obtained from a mixed integer optimization model, to produce a set of optimal schemes under different assumptions. Given the input, the MCDA allowed ranking different scenarios relying on their performance on 13 criteria covering economic, job market, quality of life of local populations, technical and environmental issues. The MCDA tool was used by a group of experts and academics with background in economics, engineering and environment. Regarding the totality of results, both the most and least expensive scenarios ranked first the same amount of times. These scenarios were, respectively, 'coal', relying mainly in new coal power plants and 'maximum renewable', relying mainly in new wind and hydro power facilities. The opinions were divided towards these two solutions with different fundamental characteristics: 'maximum renewable' with costs higher than 'coal' but leading to substantial reduction of the external energy dependency. Sensitivity analysis suggests that, although the costs are regarded as the most important criterion, those who had different rankings in their preferences have different attitudes towards other criteria.

13/03771 Implications of CO_2 reduction policies for a high carbon emitting economy

Asafu-Adjaye, J. and Mahadevan, R. *Energy Economics*, 2013, 38, 32–41.

This paper uses a dynamic computable general equilibrium model to compare the macroeconomic and sectoral impacts of three environmental policies in Australia – an emissions trading scheme (ETS), an ETS combined with technological innovation in the renewable energy sector and a fuel tax as an alternative to the ETS. Overall, the impacts of the ETS were not significantly adverse. Although the fuel tax had similar impacts to the ETS on key macro-variables such as real GDP, employment, household consumption, exports and imports, it was however not effective compared to the latter in reducing emissions. Neither policy led to inflation growth of more than 0.8% for any coal mining and non-mining Australian state. At the sectoral level, the gross domestic product growth of energy-intensive industries such as coal, iron ore, steel and coal-powered electricity generators is adversely affected while electricity generators who use gas and renewable energy sources and the forestry sector gain. It was also found that a 10% technological change in the renewable energy sector over a decade did not significantly improve the outcome when coupled with the ETS. Thus the Australian government's industry assistance to invest in low pollution technologies needs to be more aggressive to meet current and future international emission abatement targets.

13/03772 Is the energy-led growth hypothesis valid? New evidence from a sample of 85 countries

Apergis, N. and Tang, C. F. *Energy Economics*, 2013, 38, 24–31.

The energy-growth literature contains a large number of discussions on the causal relationship between energy consumption and economic growth. The central debate focuses on whether energy consumption contributes or not to economic growth since it has direct implications for the formulation of strategic policies. Nevertheless, current studies cannot provide a conclusive suggestion due to mixed causality results. This inconclusive evidence is potentially attributed to model specifications and the stage of economic development of the countries under investigation. Hence, this study attempts to empirically re-investigate the validity of the energy-led growth hypothesis using a different model specification and different stages of economic development for 85 selected countries around the globe. Overall, although the causality results are mixed among countries, a systematic pattern was found. In particular, Granger causality models with three and four variables are more likely to support the hypothesis compared to their counterparts that contain only two variables. In addition, both developed and developing countries are more likely to support the energy-led growth hypothesis compared to the less developed or low income countries. Therefore, causality results are very sensitive to the choice of the model specification along with the stages of economic development. Finally, energy conservation policies should only focus on low income countries as these policies may not retard the process of economic growth.

13/03773 Market power implication on congested power system: a case study of financial withheld strategy

Nappu, M. B. *et al. International Journal of Electrical Power & Energy Systems*, 2013, 47, 408–415.

Market power refers to the ability of generators in influencing the energy prices above competitive level to obtain more profits. It may be the cause of transmission congestion that limits transfer capability in an interconnected area. Hence an independent system operator (ISO) must be able to detect the conditions in which market power has been practised to guarantee a secure competition and economical operation of the electricity market. To cope up with transmission congestion to assess market power, an optimal power flow (OPF) based on shift-factor methodology to find out a new indicator, called congestion-based dynamic dispatch index has been proposed. One of the beneficial feature of the proposed method is the ability to recognize accurately the most potential generator to exercise the market power. A generator bidding scheme represented by financial withheld strategy is then utilized to investigate the dynamic condition of power market. An analysis on the power market performance to identify potential generators in exercising market power is also presented. The results show that transmission congestion condition may be created unnaturally by this particular bidding strategy. It prevents some cheap generators to supply their outputs and allows all more expensive generators within the congested zone to gain more profits at the cost of other market participants.

13/03774 Method and case study of quantitative uncertainty analysis in building energy consumption inventories

Lu, Y. *et al. Energy and Buildings*, 2013, 57, 193–198.

Collections of building energy consumption data are often uncertain due to unavoidable measurement errors, random errors, non-representativeness of sample data, etc. On the basis of the quantitative uncertainty and Monte Carlo uncertainty propagation methods, the uncertainty of building energy consumption data is quantified. A real case study is conducted on the electricity and gas consumptions of buildings in Ma'anshan city in China in 2009. The results show that the electricity consumption distributions of four kinds of buildings fit Weibull distribution, gamma distribution, normal distribution and lognormal distribution respectively. The total energy consumption of buildings in the city at the cumulative probability of 97.5% is 16.6% higher than that obtained using the conventional method. The uncertainty of random sampling error in total energy consumption is about 14%. The sensitivity analysis results can provide information about the main sources that can help in reducing the uncertainty of the overall energy consumption inventory. This kind of quantification of uncertainty in energy consumption inventories could assist the decision-makers in determining the likelihood of complying with energy reduction objectives, and framing more scientific energy-saving strategies that may reduce building energy consumption.

13/03775 Methods of measuring sustainable development of the German energy sector

Schlör, H. *et al. Applied Energy*, 2013, 101, 172–181.

The availability of sustainability indicators is a precondition for the conversion of the model of sustainable development into policy. Sustainability indicators define characteristics that are important for sustainable development. A single sustainability indicator defines a key issue, which characterizes a certain aspect of sustainability in the observed system. Sustainability indicator systems capture the complexity and order of the systems, and they offer new knowledge about the system that can be communicated to the general public. That is why in 2002 the German government developed a sustainability indicator set for its sustainability strategy, including indicators for a sustainability energy system within this comprehensive strategy. The government thereby defined a sustainable order for Germany based on the theme-based sustainability approach. The sustainability indicators thus have to measure the difference between the real and the normatively defined sustainability order: Do the individual preferences of society (households, enterprises) correspond to the sustainability order of the government, is the implicit preference order of society congruent with the explicit order of the government as expressed in the national sustainability strategy? The question of the measurability of sustainability is the key to the implementation of sustainable development of the energy sector. The index of sustainable development and the standardized sustainability index, developed by the authors, calculate the degree to which sustainability is achieved. Both indices show whether Germany is on a sustainable energy path according to the goals set by the German government in its strategy, but from a different perspective. The indices enabled the normatively (politically) defined sustainability order of the German government (goals) to be compared with the actual 'behaviour' of German society. Both indices helped answer the question as to whether the German energy sector is 'better off' in sustainable categories. In a monitoring process, calculations of the sustainable indicators help provide an understanding as to where political action is needed.

13/03776 The liquidity of energy stocks

Sklavos, K. *et al. Energy Economics*, 2013, 38, 168–175.

This study investigates the dynamics of stock market liquidity in the energy industry in the USA for 130 firms for the period 2006–2011. The authors use a (structural) vector autoregression approach to model the simultaneous relationships between three liquidity measures, namely turnover, price impact and spread. In addition, they account for oil prices in this model. The liquidity measures exhibit a persistent (highly autocorrelated) pattern. The intensity of trading appears to be relevant for the interrelationships of the liquidity measures. Stocks that are traded more often seem to be less sensitive to changes in liquidity. The main contribution of this study is that the authors introduce and test a specific causality pattern between trading activity, price impact, and spreads of energy stocks. This causality pattern is stronger during illiquid periods, which makes these periods much more risky.

13/03777 The role of urban form as an energy management parameter

Futcher, J. A. and Mills, G. *Energy Policy*, 2013, 53, 218–228.

Urban areas are recognized to be significant global energy consumers, and therefore high CO_2 emitters, making energy management at urban scales a relevant research focus. However, one of the main obstacles faced with upgrading existing urban systems to meet target energy reductions is the current rate of refurbishment and new build, where it is estimated that 75% of existing buildings will still be in place by 2050. Moreover limited renewable resources and predicted warming trends place further limitations on policies aimed at carbon management. This paper examines current thinking around energy management associated with building operational and regulated loads and the role of urban form. Its focus is on cooling loads for office buildings in central London and offers a new perspective on energy management at an urban scale by demonstrating (within the 25% redevelopment rate) that when building energy management is considered within an urban context, the overall performance of an urban system can be significantly improved. The work highlights the often overlooked role of urban form on building energy performance (both individually and in combination) and demonstrates that as there are moves towards a low energy future; the role of urban form becomes increasing significant.

13/03778 The strictest energy requirements in the world: an analysis of the path dependencies of a self-proclaimed success

Lauridsen, E. H. and Jensen, J. S. *Energy Policy*, 2013, 53, 97–104.

50 years of progressively strengthened energy requirements in the Danish building code appear to be a success, as the energy consumption has remained constant despite an increase in the total area in requirement of heating. This article however argues that the building code mechanism is heavily influenced by path dependent regime structuration processes, and that the mechanism constitutes a barrier to more radical developments within low energy housing. Few and poorly organized frontrunner activities within low energy housing have accordingly taken place in a Danish context during the past decades. Finally it is proposed that the current development within the energy system provides opportunities for cultivating an improved transitional awareness and for carrying out experimental activities that may challenge the path dependencies of prevailing regime structuration processes.

13/03779 Tightening the energy consumptions of buildings depending on their typology and on climate severity indexes

Salmerón, J. M. *et al. Energy and Buildings*, 2013, 58, 372–377.

This paper aims to present the more recent advances regarding the climatic zoning based on the Climate Severity Index and its relation with the building energy requirements. Three are the major contributions in this paper, the first one is the comparison of the energy performance requirements in different European Union member states; secondly the definition of the global climate severity index, and finally the definition of the climate severity index for tertiary buildings. Regulators and building designers are the most interested in these results. The comparison of the energy requirements, gives to the regulators, valuable information in order to establish a consistent requirement in their own country. Thanks to the definition of the global climate severity index, the previous can be done in terms of global-heating plus cooling-energy needs, allowing a homogeneous comparison in Europe or worldwide. Also, these results allow comparing the energy requirements in one country to those with similar climate. From the designer point of view, the results of this paper could be used to estimate the thermal properties – *U*-values – of the building envelope, and the solar shading factor of the windows of a tertiary building assimilating it to a residential building in an equivalent climatic zone.

Energy conservation

13/03780 Analysis on energy-saving effect and environmental benefit of a novel hybrid-power gas engine heat pump

Wang, Y. *et al. International Journal of Refrigeration*, 2013, 36, (1), 237–246.

Taking a novel hybrid-power gas engine heat pump (HPGHP) as an example, fuel-consumed rate, fuel-consumed flow, fuel conversion efficiency and life cycle assessment were used to analyse energy-saving effect and natural gas environmental benefits on human health, ecosystem quality and resource consumption through contrast with electric power consumption model. The test results show that the fuel conversion efficiency under different operating conditions of HPGHP is higher than conventional gas engine heat pump under the same load. Besides, from the total indicator, scores on resource consumption is the highest. Gaseous product is mainly CO_2 and other carbon or sulfur oxide gases are discharged in form of negative or water body, which means the use of natural gas effectively control the pollution gas emissions. At last, concept of environmental benefit time was established; the result shows that HPGHP can embody better environmental benefits than gas heat pump when running more than 1778 h.

13/03781 Case study: the effects of a variable flow energy saving strategy on a deep-mine cooling system

du Plessis, G. E. *et al. Applied Energy*, 2013, 102, 700–709.

Cooling systems consume up to 25% of the total electricity used on deep level mines. These systems are integrated with the water reticulation system to provide chilled service water to the mine as well as cooling for mine ventilation air. Although there is definite potential for demand-side management on these systems, it is critical that the service delivery be maintained so as not to adversely affect productivity. An energy saving strategy based on variable water flow was developed for the unique demands of integrated mine cooling systems. The strategy is based on matching the evaporators with the demand of chilled water; condensers adapting to the heat load; and the bulk air cooler matching the demand of ventilation air requirements. In this paper, a case study is presented in which the savings and consequences of implementing the developed energy saving strategy are investigated. It is shown that a decrease of 31.5% in overall electrical energy usage is possible without affecting the service delivery or performance of the cooling system.

13/03782 Changes in mouldboard plough draught and tractor fuel consumption on continuous corn after 18 years of organic and inorganic N amendments

Liang, A. *et al. Energy*, 2013, 52, 89–95.

It is well documented that organic N amendments helps to increase soil organic carbon and improve other soil properties, and some reports also show an accompanying reduction in energy for tillage for short-term application of organic N amendments. The influence of soil inorganic and organic N amendments on soil organic carbon is complex and long-term effects on energy for tillage are unknown. A field experiment was conducted where inorganic and organic soil N amendments consisting of none, inorganic fertilizer at 100 and 200 $kg\,ha^{-1}$ N, and stockpiled manure (SM) and rotted manure (RM) each at 50 and 100 $Mg\,ha^{-1}$ (wet weight) were applied annually to continuous corn for 18 years. Mouldboard plough draught and tractor fuel consumption measurements were made during annual fall tillage in selected years. The organic amendments significantly reduced both mouldboard plough draught and tractor fuel consumption compared to inorganic N fertilizer or no amendment with the rotted manure showing larger reduction than stockpiled manure at the same rate, and higher manure rates showing greater difference than lower manure rates. There was a general trend for an increase in the difference with time. After 18 years, plough draught and tractor fuel consumption for the 100 $Mg\,ha^{-1}$ RM treatment were 41% and 22%, respectively, less than the no amendment treatment. Decaying exponential models predict that about 80–94% of the maximum change in draught has occurred after 18 years of annual N amendment application.

13/03783 Economic evaluation and calculations of energy savings by upgrading the heating systems in pre manufactured homes

Elsawaf, N. *et al. Energy and Buildings*, 2013, 59, 187–193.

This study evaluates the energy consumption in houses for low-income families during the heating seasons, and estimates the savings associated with upgrading the heating systems. The study tests the effectiveness of using air-source heat pumps for space heating in north-east Carolina. Economic evaluation of the heating system is performed based on the collected data which includes surveys, actual energy consumption. Results show that houses with heat pumps as the main source of heating have the lowest energy consumption and the lowest energy intensity. Heat pumps are found to reduce the heating cost in low-income mobile homes by up to 52% when integrated in an electric strip heat system and at the same time improves the thermal comfort. Moreover, results from the economic and sensitivity analyses support an economic justification for using heat pumps as their benefits exceed the initial cost of installation as evident by the positive net present value and the greater than one profitability index ratios especially after the second year of installation and throughout the 15 years – life of the heat pump retrofits.

13/03784 Energy conservation through energy service companies: empirical analysis from China

Kostka, G. and Shin, K. *Energy Policy*, 2013, 52, 748–759.

China's energy-service companies (ESCOs) have developed only modestly despite favourable political and market conditions. Here it is argued that with sophisticated market institutions still evolving in China, trust-based relations between ESCOs and energy customers are essential for successful implementation of energy efficiency projects. Chinese ESCOs, who are predominantly small and private enterprises, perform poorly in terms of trust-building because they are disembedded from local business, social, and political networks. It is concluded that in the current institutional setting, the ESCO model based on market relations has serious limitations and is unlikely to lead to large-scale implementation of energy efficiency projects in China.

13/03785 Energy efficiency improvement and fuel savings in water heaters using baffles

Sedeh, M. M. and Khodadadi, J. M. *Applied Energy*, 2013, 102, 520–533.

Thermal efficiency improvement of a water heater was investigated numerically and experimentally in response to presence of a baffle, particularly designed for modifying the flow field within the water reservoir and enhancing heat transfer extracted into the water tank. A residential natural gas-fired water heater was selected for modifying its water tank through introducing a baffle for lowering natural gas consumption by 5% as a target. Based on the geometric features of the selected water heater, three-dimensional models of the water heater subsections were developed. Upon detailed studies of flow and heat transfer in each subsection, various sub-models were integrated to a complete model of the water heater. Thermal performance of the selected water heater was investigated numerically using computational fluid dynamics analysis. Prior to baffle design process and in order to verify the developed model of the water heater, time-dependent numerically-predicted temperatures were compared to the experimentally measured temperatures under the same conditions at six different locations inside the water tank and good agreement was observed. Upon verifying the numerical model, the fluid flow and heat transfer patterns were characterized for the selected water heater. The overall design of the baffle and its location and orientation were finalized based on the numerical results and a set of parametric studies. Finally, two baffle designs were proposed, with the second design being an optimized version of the first design. The verified three-dimensional model of the water heater was modified to include the baffle designs and same thermal performance analysis was simulated confirming potential improvements in thermal efficiency. Thereafter, designed baffles were prototyped and assembled in identical water heater units and experiments were conducted according to standard water heater test procedures. Finally, numerical and experimental results verified thermal efficiency improvement in the water heater after introducing the baffles. As a result, baffle's second design is capable of lowering the natural gas consumption of the water heater by 4.95% under steady-state thermal efficiency test condition which meets the target of this research. However, the gas savings under actual usage patterns might be less than this value.

13/03786 Energy efficiency of elevated water supply tanks for high-rise buildings

Cheung, C. T. *et al. Applied Energy*, 2013, 103, 685–691.

High-rise housing, a trend in densely populated cities around the world, increases the energy use for water supply and corresponding greenhouse gas emissions. This paper presents an energy efficiency evaluation measure for water supply system designs and a mathematical model for optimizing pumping energy through the arrangement of water tanks in a building. To demonstrate that the model is useful for establishing optimal design solutions that integrate energy consumption into urban water planning processes which cater to various building demands and usage patterns, measurement data of 22 high-rise residential buildings in Hong Kong are employed. The results show the energy efficiency of many existing high-rise water supply systems is about 0.25 and can be improved to 0.26–0.37 via water storage tank relocations. The corresponding annual electricity that can be saved is 160–410 TJ, a 0.1–0.3% of the total annual electricity consumption in Hong Kong.

13/03787 Energy saving potential of a hybrid ventilation system integrated with heat storage material

Kwon, O.-H. *et al. Energy and Buildings*, 2013, 57, 346–353.

This study proposes a hybrid ventilation system to reduce indoor heating and cooling loads owing to ventilation by using the heat storage and discharge effects of some heat storage materials. A pilot system of the ventilating system, comprised of heat storage material, a filter, as well as supply and exhaust fans, was also built. To measure the energy saving performance of the system, the following quantitative indicators were used: heat storage time, heat discharge time, heat storage material efficiency and reduction of ventilation loads. These indicators were measured based on actual data gathered from four test operations. The result shows that polycarbonate-based heat storage material has a longer heat discharge time compared to heat storage time, and a reduced ventilation heating load by over 37%.

13/03788 Energy use pattern in rice production: a case study from Mazandaran province, Iran

AghaAlikhani, M. *et al. Energy Conversion and Management*, 2013, 69, 157–162.

Rice (*Oryza sativa* L.) is grown under both the traditional system (TS) and a mechanized system (MS) in Iran. In this study, the energy consumption for rice production is analysed in Mazandaran, a northern province of Iran. The indicators are: net energy, energy use efficiency, specific energy, energy productivity, direct energy, indirect energy, renewable energy, non-renewable and total energy input. The cultivars of rice commonly grown in Iran are listed in three groups: native, high yield cultivars and hybrid cultivar. Primary data were obtained through field survey and personal interviews using questionnaires from 48 agricultural service centres in Mazandaran province. Secondary data and energy equivalents were obtained from available literature using the collected data for the production period 2007–2008. The analysis of the data showed that on average, diesel fuel had the highest share within the total energy inputs, followed by chemical fertilizer in rice production in both TS and MS. Energy use efficiency was calculated as 1.72 in TS and 1.63 in MS. Total energy consumption in rice production was 71,092.26 and 79,460.33 MJ/ha for TS and MS, respectively. In general, there were not significant differences regarding human labour and chemical use in the two systems.

13/03789 Fuel consumption reduction in urban buses by using power split transmissions

Macor, A. and Rossetti, A. *Energy Conversion and Management*, 2013, 71, 159–171.

The reduction of fuel consumption of urban vehicles is one of the challenges of the society today. Many promising technologies such as hybrid electric vehicles and fuel cells are the focus of a lot of research and investments, but high costs prevent their development on a large scale, especially in heavy-duty vehicles. Simpler solutions, such as continuously variable transmissions, are then interesting alternatives: they preserve some of the advantages of hybrid solutions significantly reducing the overall cost of the system. Since these technologies allow the decoupling of the engine's velocity from that of the wheels, optimized management of the engine becomes feasible, leading to lower fuel consumption than that of traditional solutions. This work compares the hydromechanical transmission with a traditional power shift in an application where efficiency and comfort are required: a city bus. The performance of a vehicle with a dual stage hydromechanical transmission has been investigated by means of a model implemented in the AMESim environment. A second model of a vehicle with a power shift transmission has been taken as reference solution. During the simulation of two standard test cycles, the first vehicle showed the lower fuel consumption, due to its better engine management, and to the operation of the torque converter during starts, which lowers the efficiency of the reference vehicle.

13/03790 Improved firefly algorithm approach applied to chiller loading for energy conservation

dos Santos Coelho, L. and Mariani, V. C. *Energy and Buildings*, 2013, 59, 273–278.

Significant energy savings can be achieved by optimizing chiller operation and design in heating, ventilation and cooling (HVAC) systems. In terms of optimization, various metaheuristics have been proposed to the optimal chiller loading problem. New metaheuristics are also emerging recently, between them the firefly algorithm. Firefly algorithm is a nature inspired algorithm based on the idealized behaviour of the flash pattern and characteristics of fireflies. This study proposes a new improved firefly algorithm (IFA) based on Gaussian distribution function to the optimal chiller loading design. To testify the performance of the proposed method, the paper adopts two case studies comparing the results of the developed model using IFA with those of traditional firefly algorithm and other optimization methods in literature. In this paper, the optimization problem is minimize energy consumption of multi-chiller systems, where the objective function is energy consumption and the optimum parameter is the partial loading ratio of each chiller. The results of both case studies show that the proposed IFA outperform several optimization methods of the literature in terms of minimum energy consumption solution of the optimal chiller loading problem.

13/03791 Improving the energy efficiency in buildings while reducing the waste using autoclaved aerated concrete made from power industry waste

Drochytka, R. *et al. Energy and Buildings*, 2013, 58, 319–323.

Production of autoclaved aerated concrete (AAC) from power industry waste cinders represents a progressive technology for processing of industrial waste in a new form of building material with good qualities. Despite these positive aspects, the share of cinder concrete in the building industry is less popular. The low popularity is partially caused by the poor aesthetic of cinder concrete in comparison with sand-based AAC; however, the main cause is the slightly smaller thermal and moisture qualities of fly ash-based AAC, respecting uncertainty because there are no supporting scientific research and publications about it. This paper is dedicated to a study of the thermal and moisture properties of the cinder concrete and mutual behaviour with the sand-based AAC. It was determined that fly ash-based AAC demonstrated slightly larger moisture sorption in comparison with sand-based concrete under similar conditions. On the contrary, the thermal insulating properties of fly ash-based concrete, as indicated by the heat conductivity, exhibits less moisture influence in comparison with sand-based AAC. Concerning volume changes, fly ash-based AAC showed, in the condition of low moisture, slightly better properties when compared with autoclaved aerated sand concrete.

13/03792 Intensified thermal integration in batch reactive distillation

Maiti, D. *et al. Applied Energy*, 2013, 103, 290–297.

Published work on the heat integration of batch distillation is scare and mainly focuses on the continuous flow columns. This paper introduces a novel thermally integrated batch reactive distillation, in which, the rectification tower runs as usual at atmospheric pressure and the concentric reboiler operates under vacuum. It is inspected that the proposed thermally integrated batch reactive distillation with a concentric vacuum reboiler secures positive savings of energy and better economic figures than the conventional batch reactive distillation. Importantly, this scheme has the potential to enhance the product purity at steady state by the improvement of reaction conversion. For boosting both the energetic and economic performance of the proposed thermally integrated batch distillation scheme, in this contribution, further intensification was introduced by coupling the overhead vapour and the reboiler liquid.

13/03793 Layering residential peer networks and geospatial building networks to model change in energy saving behaviors

Chen, J. and Taylor, J. E. *Energy and Buildings*, 2013, 58, 151–162.

Complex human or engineered network systems can be examined as a series of coexisting layers. A variety of dynamic perturbations, such as information flows across computer networks, traffic flows across transportation networks and the spread of energy-saving practices across human networks, have been treated separately as single networks in previous research. However, because these phenomena often consist of human networks interacting with engineered networks, analysing the properties of the multi-layer network systems may provide more accurate insights. This paper examines a multi-layer network system to provide insight into the diffusion of energy consumption practices through peer networks within and across residential buildings. The authors introduce a new model – the layered network model – that treats that treats a residential peer network and a geospatial building network as a single, layered network. They compare this model to a previously published multi-layer interactive network model by simulating diffusion through a real multi-layer network system consisting of a residential peer network and a geospatial building network from three experimental data-sets. The authors' model was found to be more accurate and efficient, hence contributing an efficient mathematical model and set of simulation algorithms that accurately capture the post-perturbation response of a layered, residential peer network and a geospatial building network.

13/03794 Lighting control system based on digital camera for energy saving in shop windows

Carrillo, C. *et al. Energy and Buildings*, 2013, 59, 143–151.

Shop window lighting usually represents a meaningful quantity in the lighting consumption of a shop because the large amount of installed power and its high number of running hours. Dimming of lighting can improve its energy efficiency, however, conventional systems, as photocell detectors, are difficult to be used. Besides, the usual control objective of daylight harvesting cannot be applied in this context because here the main objective is to maintain the attractiveness on shop window. In this paper, a control system for shop window lighting is proposed. In this system, a digital camera as a luminance meter has been used. Furthermore, the main objective of the controller is to keep constant the contrast of the shop window interior with respect to its surroundings. The proposed control has been tested in a shop window prototype where real working conditions have been simulated.

13/03795 Optimum combinations of building envelop energy-saving technologies for office buildings in different climatic regions of China

Zhou, S. and Zhao, J. *Energy and Buildings*, 2013, 57, 103–109.

With the economic development, the energy consumption of office buildings is growing increasingly in China. The building envelop energy-saving technology (BEEST) needs to be optimized in order to improve the energy performance of office buildings. In this paper, an office building with the representative building design was selected as the building model. The BEESTs were used to improve the energy performance of exterior walls, roof and exterior windows. By the use of energy simulation software, the energy-saving effects of different BEESTs were calculated and compared with each other in the five major climatic regions of China. Then a new method which combined energy simulation with economic analysis was proposed to evaluate the optimum EPS insulation thickness. Based on sensitivity analysis, the economic EPS insulation thickness for exterior wall and roof was obtained. Finally, the optimum combinations of the BEESTs suitable for the office buildings in different climatic regions were put forward respectively and the comprehensive energy-saving effects of the optimum combinations were also evaluated.

13/03796 Potential energy savings made by using a specific control strategy when tumble drying small loads

Stawreberg, L. and Nilsson, L. *Applied Energy*, 2013, 102, 484–491.

Tumble dryers manufactured today are optimized for their maximum capacity, i.e. 6–8 kg of dry load. An average washing load in ordinary households lands at between 2 and 3.5 kg dry load, which implies that the drying load is even smaller. The energy efficiency decreases with reduced drying load. The aim of this study is to establish a mathematical model for studying alternative control strategies for the venting tumble dryer in order to increase the energy efficiency of drying small loads. Two series of test runs were performed: the first series with three different drying loads was used as reference tests for validation of the mathematical model, and the second series was performed with airflow reduction. The model shows good agreement with the test runs. Two control strategies were tested using the model on the smallest drying load. By lowering the heat supply to the heater and by reducing the airflow, the energy efficiency increases by 6% in a small load drying cycle. It was not possible, however, for the investigated dryer, to reach the same energy efficiency for small loads as for the maximum drying load by using a control strategy.

13/03797 Potential of energy savings through implementation of energy conservation building code in Jaipur city, India

Tulsyan, A. *et al. Energy and Buildings*, 2013, 58, 123–130.

The potential impact of the energy conservation building code (ECBC) of India, that is applicable on commercial buildings having more than 100 kW connected load or 120 kVA contract demand, has been analysed on six different type of buildings in Jaipur. Calibrated simulation models of these buildings have been created using their existing specifications to estimate the energy saving potential through ECBC. It has been found that the specific energy consumption of these buildings lie in the range of 137 kWh/m^2/y for the case of government building to 386 kWh/m^2/y for the private office. The energy saving potential with ECBC is in the range of 44 kWh/m^2/y in government buildings as lowest effect, whereas in case of the private office, it is estimated to be 128 kWh/m^2/y. Percentage energy savings with ECBC compliance in these buildings vary from 17% in the case of institutional building to 42% in the case of Hospital building. Using these estimates and the trend of increase in commercial building energy consumption, the potential of energy saving in the city of Jaipur has been identified as 12,475 MWh/y in the next 5 years.

13/03798 Potentials for energy savings and long term energy demand of Croatian households sector

Pukšec, T. *et al. Applied Energy*, 2013, 101, 15–25.

Households represent one of the most interesting sectors when analysing Croatia's energy balance. This sector makes up one of the largest energy consumers with around 75 PJ per year, which is almost 29% of Croatia's final energy demand. Considering this consumption, implementing various mechanisms, which would lead to improvements in energy efficiency of this sector, seems relevant. In order to plan future energy systems, it would be useful to know future possibilities and needs regarding energy demand of the different sectors. Long-term energy demand projections of the Croatian household sector will be considered in this paper. The focus of the paper will be on various mechanisms that influence future energy demand scenarios. It would be useful to quantify this influence, either positive or negative, and see which mechanisms would be the most significant. Energy demand projections in this paper are based on the bottom-up approach model that combines and processes a large number of input data. The model will be compared to the Croatian National Energy Strategy and certain differences and conclusions will be presented. One of the major conclusions shown in this paper are the significant possibilities for energy efficiency improvements and lower energy demand in the future, based on careful and rational energy planning. Different financial, legal and technological mechanisms can lead to significant savings in the household sector which leads to lower greenhouse gas emissions and lower Croatian dependence on foreign fossil fuels.

13/03799 Predicting the diversity of internal temperatures from the English residential sector using panel methods

Kelly, S. *et al. Applied Energy*, 2013, 102, 601–621.

In this paper, panel methods are applied in new and innovative ways to predict daily mean internal temperature demand across a heterogeneous domestic building stock over time. This research not only exploits a rich new dataset but presents new methodological insights and offers important linkages for connecting bottom-up building stock models to human behaviour. It represents the first time a panel model has been used to estimate the dynamics of internal temperature demand from the natural daily fluctuations of external temperature combined with important behavioural, socio-demographic and building efficiency variables. The model is able to predict internal temperatures across a heterogeneous building stock to within ~0.71 °C at 95% confidence and explain 45% of the variance of internal temperature between dwellings. The model confirms hypothesis from sociology and psychology that habitual behaviours are important drivers of home energy consumption. In addition, the model offers the possibility to quantify take-back (direct rebound effect) owing to increased internal temperatures from the installation of energy efficiency measures. The presence of thermostats or thermostatic radiator valves (TRVs) are shown to reduce average internal temperatures, however, the use of an automatic timer is shown to be statistically insignificant. The number of occupants, household income and occupant age are all important factors that explain a quantifiable increase in internal temperature demand. Households with children or retired occupants are shown to have higher average internal temperatures than households who do not. As expected, building typology, building age, roof insulation thickness, wall U-value and the proportion of double glazing all have positive and statistically significant effects on daily mean internal temperature. In summary, the model can be either used to make statistical inferences about the importance of different factors for explaining internal temperatures or as a predictive tool. However, a key contribution of this research is the possibility to use this model to calibrate existing building stock for behaviour and socio-demographic effects leading to improved estimations of domestic energy demand.

13/03800 Saving money vs investing money: do energy ratings influence consumer demand for energy efficient goods?

Panzone, L. A. *Energy Economics*, 2013, 38, 51–63.

The article analyses economic barriers leading to the energy efficiency gap in the market for energy-using products by observing several million transactions in the UK over 2 years. The empirical exercise estimates 'almost ideal demand system' models for refrigerators, washing machines, television, and light bulbs. Results indicate that market barriers are crucial in the demand for energy efficient options, and consumer response to changes in appliance prices, total expenditures, and energy prices depends on the possibility of behavioural adjustments in consumption. In contrast with the induced innovation hypothesis, current electricity prices can fail to induce innovation because of their short-term impact on disposable income, while consumers invest in energy efficiency when expecting electricity prices to rise in the future.

13/03801 Shading and available energy in a parabolic trough concentrator field

Sharma, V. M. *et al. Solar Energy*, 2013, 90, 144–153.

A shadow cast by one collector row on its adjacent one in a solar collector field affects the energy collection. Due to continuous change in sun's position, shadow and its effect on adjacent row also change with time. For any orientation of collector field, extent of shading depends upon the gap between the rows. It is necessary to have enough gap between the rows to avoid shading for maximum time of the day resulting in the highest energy collection. However, the availability of open land puts constraints on the gap. The present work aims at finding the energy available for a collector field for any pitch, any orientation and any latitude considering shading. A factor called annual energy availability factor has been defined to quantify the annual energy availability at the aperture of a collector field. It is found that this factor increases significantly with increase in pitch initially and later saturates with no substantial improvement in energy collection. Performances of collector field for different orientations have also been compared. It is found that N–S mounted collector field is the best in terms of energy availability considering shading. This orientation also leads to the least cost of electricity generation. From this work, one can predict the energy availability and cost of energy production for any location, orientation and pitch. One can also choose the minimum pitch required to meet a particular energy availability requirement for given location and orientation.

13/03802 Sustainability assessment of renovation packages for increased energy efficiency for multi-family buildings in Sweden

Brown, N. W. O. *et al. Building and Environment*, 2013, 61, 140–148.

This paper proposes a method for assessing renovation packages drawn up with the goal of increasing energy efficiency. The method includes calculation of bought energy demand, life-cycle cost (LCC) analysis and assessment of the building according to the Swedish environmental rating tool Miljöbyggnad (MB). In this way the methodology assesses economic, indoor environmental quality (IEQ) and specifically environmental aspects associated with energy demand of such packages from a sustainability point of view. Through MB, energy efficiency packages are placed in context with other necessary measures required to improve environmental performance in buildings, providing a consistent and systematic basis other than simply financial performance by which to compare capital improvements. The method is further explained and analysed by applying it in three case studies. In each case study a multi-family building representing a typologically significant class in the Swedish building stock is considered, and for each building a base case and two renovation packages with higher initial investment requirement and higher energy efficiency are defined. It is shown that higher efficiency packages can impact IEQ indicators both positively and negatively and that packages reducing energy demand by approximately 50% have somewhat higher LCC. Identified positive IEQ impacts point to added value for packages that may not otherwise be communicated, while negative impacts identify areas where packages need to be improved, or where MB indicators may be referred to as specifications in procurement procedures.

13/03803 Swimming pools as heat sinks for air conditioners: California feasibility analysis

Harrington, C. and Modera, M. *Energy and Buildings*, 2013, 59, 252–264.

Earlier studies used field testing of swimming pool temperatures to validate a mathematical model for predicting the temperature of an unheated pool. Combining those results with manufacturers' data on the performance of vapour-compression air conditioners as a function of heat rejection temperature, the analyses in the paper suggest that rejecting air conditioning heat to a swimming pool can save approximately 25–30% of single-family residential cooling electricity use and reduce cooling electricity demand during peak conditions by 30–35%, as compared to using the same compressor to reject the heat to ambient air. The savings is expected to vary depending on the severity of the climate, as well as the pool temperature experienced during the summer. The original model was refined so as to accommodate air-conditioner heat rejection to predict pool temperatures based on weather data, pool size, shading of the pool, and air-conditioner heat rejection to the pool. The results of an experimental validation of the augmented pool thermal model are presented here. In addition, the model of a pool-coupled air conditioning system was used to develop a design tool for determining the pool size needed to absorb realistic heat rejection from air conditioners in various California climate zones.

17 ENERGY CONVERSION AND RECYCLING

13/03804 A dynamic model for thermoelectric generator applied in waste heat recovery

Gou, X. *et al. Energy*, 2013, 52, 201–209.

Thermoelectric devices can provide clean energy conversion and are environmentally friendly. However, few studies have been conducted to understand the dynamic characteristics of thermoelectric generators (TEGs). The stability of output performance plays a very important role in TEG. Based on the thermoelectric effect and heat transfer theory, a dynamic model for waste heat recovery in a general TEG was developed to assess the influence of heat reservoir and heat sink. The validity of the theoretical model was demonstrated by experiments and it was found that the model prediction agrees well with the experimental results. The dynamic response characteristics, such as hot and cold semiconductor surface temperatures, maximum output power and system efficiency, were studied using this dynamic model. The results showed that enhancing heat dissipation on cold side is the crucial to improve the output performance of TEG, and that the fluctuation of hot reservoir leads to rapid change of output power generated by TEG, which is dangerous to electric devices. The dynamic model proposed in the present study can be used in the design and operation analysis of TEGs.

13/03805 AFBC of coal with tyre rubber. Influence of the co-combustion variables on the mineral matter of solid by-products and on Zn lixiviation

Díaz-Bautista, M. A. *et al. Fuel*, 2013, 106, 10–20.

The study focuses on the generation and distribution of mineral species in fly and bottom ashes. These were formed during a fluidized co-combustion of a fossil fuel (coal) and a non-fossil fuel (tyre rubber) in a small fluidized bed combustor (7 cm × 70 cm). The pilot plant had continuous fuel feed using varying ratios of coal and rubber. The study also focuses on the lixiviation behaviour of metallic elements with the assessment of zinc recovering. The conclusions of the study were as follows. The conversion of tyres to energy in an atmospheric fluidized combustion offers the advantages of a high calorific power and a minimum moisture and mineral matter content, making it a proper fuel to generate energy when mixed with other fuels, for example high ash coals. The coal/rubber mixtures combustion leads to higher zinc concentrations in fly ash than in bottom ash. The zinc recovering of fly ash from the coal/rubber mixtures is always greater than from bottom ashes due to the smaller evolution of zinc mineral species in the fly ash. Acid lixiviation provides the best zinc extraction results. By increasing lixiviation time and temperature an increase in zinc extraction is observed.

13/03806 Application of refuse fuels in a direct carbon fuel cell system

Ahn, S. Y. *et al. Energy*, 2013, 51, 447–456.

Refuse-derived fuel (RDF) and refuse plastic/paper fuel (RPF) were evaluated in a direct carbon fuel cell (DCFC) system as energy sources, and two different grades of coals were also employed for comparison. The maximum power density of refuse fuels was reached up to 43–62% level comparing to that of coals, despite their significantly low carbon content. Significant properties such as thermal reactivity, nitrogen gas adsorption characteristics, and functional groups on the surface of the fuel were investigated using the thermogravimetric analysis, Brunauer–Emmett–Teller test and X-ray photoelectron spectroscopy techniques, respectively. The correlation between fuel properties and electrochemical reactions was investigated, and it was found that the total carbon content, surface area, pore volume, and oxygen functional groups on the surface might have an influence on the reactions in the DCFC system. The effect of temperature increase from 973 to 1023 K was restricted in the RDF because of its highly activated gasification phenomenon. The stirring effect could improve the performance of the RDF and the RPF only at 1023 and 923 K, respectively, because of thermal characteristics and certain substances that affected the viscosity of the electrolyte.

13/03807 Catalytic conversion of waste high-density polyethylene into useful hydrocarbons

Jan, M. R. *et al. Fuel*, 2013, 105, 595–602.

Waste high-density polyethylene (HDPE) was catalytically degraded using $CaCO_3$ as a basic catalyst. Various parameters like temperature, catalyst-to-polymer ratio (cat/pol) and reaction time were explored in order to find out optimum reaction conditions. Total conversion of 97.20% was achieved with 52.33% oil yield and 53.84% oil selectivity. Sufficient quantity of the oil product was collected for further physicochemical study. The oil obtained was fractionated at different temperatures and physical parameters were studied for all the fractions including parent catalytic oil. The ASTM distillation study of the catalytically derived oil showed that its 40% fraction was in the boiling point range of light naphtha, 24% fraction was in the range of heavy naphtha and 36% fraction was in the boiling point range of middle distillate. The oils obtained were analysed by GC/MS to find out their composition. Major constituent hydrocarbons were found to be in the range of C_7–C_{28} distributed in various fractions derived at different temperatures. Different fractions showed varied compositions with constituents common to two or more sample fractions showing overlap of the distillation ranges. As a result of comparing the physical parameters of the sample oils with standard fuels it was observed that the collected fractions were either in the range of gasoline, kerosene or diesel oil.

13/03808 Compressed air energy storage (CAES) with compressors distributed at heat loads to enable waste heat utilization

Safaei, H. *et al. Applied Energy*, 2013, 103, 165–179.

Large scale penetration of renewable energies such as wind and solar into the electric grid is complicated by their intermittency. Energy storage systems can mitigate these fluctuations by storing off-peak energy for use at peak-demand times. Compressed air energy storage (CAES) is one of the most promising storage technologies due to the large amount of energy that can be stored at an economical cost. The authors evaluate the feasibility of improving the economics of CAES by distributing compressors near heat loads to enable recovery of the heat of compression to supply low-grade heating needs such as district heating. Distributed CAES (DCAES) is more efficient; however, it has higher capital costs due to the compressed air pipeline required between distributed compressors and the storage site. The authors evaluate the project economics of DCAES in a hypothetical scenario with a variable electric and heat load. The size and dispatch of a generation fleet composed of a wind farm, CAES or DCAES plant and conventional gas turbines are optimized to satisfy the annual electricity load at an hourly resolution at the lowest total cost. It was found that the total cost of supplying heat and electric loads is less expensive with DCAES given a 50 km pipeline when fuel prices exceed $7.6/GJ. The cross-over fuel price depends on the distance as it drives the capital cost of the pipeline. The minimum effective fuel price required for economic superiority of the DCAES system is $7.0/GJ and $8.3/GJ at pipeline lengths of 25 and 100 km, respectively.

13/03809 Ensiling of fish industry waste for biogas production: a lab scale evaluation of biochemical methane potential (BMP) and kinetics

Kafle, G. K. *et al. Bioresource Technology*, 2013, 127, 326–336.

This study evaluated how fish waste (FW) obtained from a fish processor was ensiled for biogas production. The FW silages were prepared by mixing FW with bread waste (BW) and brewery grain waste (BGW), and the quality of the prepared silages were evaluated. The biogas potentials of BW, BGW, three different types of FW, and FW silages were measured. A first-order kinetic model and the modified Gompertz model were also used to predict methane yield. The biogas and methane yield for FW silages after 96 days was calculated to be 671–763 mL/g volatile solids (VS) and 441–482 mL/g VS, respectively. There were smaller differences between measured and predicted methane yield for FW silages when using a modified Gompertz model (1.1–4.3%) than when using a first-order kinetic model (22.5–32.4%). The critical hydraulic retention times and technical digestion times ($T_{80–90}$) for the FW silages were calculated to be 21.0–23.8 and 40.5–52.8 days, respectively.

13/03810 Generalized predictive control applied in waste heat recovery power plants

Zhang, J. *et al. Applied Energy*, 2013, 102, 320–326.

A multivariable control strategy is needed to ensure high efficiency and load-following capability in the operation of waste heat recovery power plants. In this paper, a generalized predictive controller is proposed for a waste heat recovery process operating on an organic Rankine cycle. The simulation results show that the proposed control strategy not only can achieve good transient and steady response along with decoupling performance, but also can obtain satisfactory disturbance rejection performance.

13/03811 High yield hydrogen from the pyrolysis–catalytic gasification of waste tyres with a nickel/dolomite catalyst

Elbaba, I. F. and Williams, P. T. *Fuel*, 2013, 106, 528–536.

Nickel/dolomite catalysts have been prepared and investigated for their suitability for the production of hydrogen from the two-stage pyrolysis–gasification of waste tyres. Experiments were conducted at a pyrolysis temperature of 500 °C and gasification temperature was kept constant at 800 °C with a catalyst/waste tyres ratio of 0.5. Fresh and reacted catalysts were characterized using a variety of methods, including, BET, X-ray diffraction (XRD), thermogravimetric analysis (TGA) and scanning electron microscopy (SEM)–energy dispersive X-ray spectrometry (EDXS). The results indicated that the gas yield was significantly increased from 30.3 to 49.1 wt% and the potential H_2 production was doubled with the introduction of 5%Ni into the calcined dolomite catalyst. The results show also a further increase in the gas yield and the potential H_2 production with increasing Ni loading from 5 to 20 wt%. The coke deposited on the catalyst surface was 3.1, 0.9, 2.8 and 3.7 wt%, when the Ni loading was 0, 5, 10 and 20 wt% for the calcined dolomite catalyst, respectively. The results showed that the calcined Ni dolomite catalysts became deactivated by filamentous carbons.

13/03812 Microwave assisted transesterification of waste frying oil and concentrate methyl ester content of biodiesel by molecular distillation

Azcan, N. and Yilmaz, O. *Fuel*, 2013, 104, 614–619.

In this study, microwave assisted transesterification of waste frying oil was carried out in the presence of sodium methoxide ($NaOCH_3$). Parametric studies were performed to investigate suitable reaction conditions such as catalyst amount (0.5–0.75–1.0–1.5 wt%), reaction time (3–5–7–9 min), temperature (55–60–65 °C), and oil:methanol ratio (1:4–1:5–1:6). Methyl ester content of biodiesel was determined as 90.04–98.85%. Methyl ester content of biodiesel was increased from 90.04% to 97.74% by molecular distillation at 170–200 °C, 10 mbar and 0.12–0.24 mL/min feed flow rate. Optimum distillation conditions were determined as 0.18 mL/min feed flow rate and 170 °C evaporator temperature by using 4×3 factorial design.

13/03813 Multi-objective optimization of an organic Rankine cycle (ORC) for low grade waste heat recovery using evolutionary algorithm

Wang, J. *et al. Energy Conversion and Management*, 2013, 71, 146–158.

The organic Rankine cycle (ORC) can effectively recover low grade waste heat due to its excellent thermodynamic performance. Based on the examinations of the effects of key thermodynamic parameters on the exergy efficiency and overall capital cost, multi-objective optimization of the ORC with R134a as working fluid is conducted to achieve the system optimization design from both thermodynamic and economic aspects using non-dominated sorting genetic algorithm-II (NSGA-II). The exergy efficiency and overall capital cost are selected as two objective functions to maximize the exergy efficiency and minimize the overall capital cost under the given waste heat conditions. Turbine inlet pressure, turbine inlet temperature, pinch temperature difference, approach temperature difference and condenser temperature difference are selected as the decision variables owing to their significant effects on the exergy efficiency and overall capital cost. A Pareto frontier obtained shows that an increase in the exergy efficiency can increase the overall capital cost of the ORC system. The optimum design solution with their corresponding decision variables is selected from the Pareto frontier. The optimum exergy efficiency and overall capital cost are 13.98% and US$129.28 $\times 10^4$, respectively, under the given waste heat conditions.

13/03814 Optimization of a microbial fuel cell for wastewater treatment using recycled scrap metals as a cost-effective cathode material

Lefebvre, O. *et al. Bioresource Technology*, 2013, 127, 158–164.

Microbial fuel cell (MFC) for wastewater treatment is still hindered by the prohibitive cost of cathode material, especially when platinum is used to catalyse oxygen reduction. In this study, recycled scrap metals could be used efficiently as cathode material in a specially-designed MFC. In terms of raw power, the scrap metals ranked as follows: W/Co > Cu/Ni > Inconel 718 > carpenter alloy; however, in terms of cost and long-term stability, Inconel 718 was the preferred choice. Treatment performance – assessed on real and synthetic wastewater – was considerably improved either by filling the anode compartment with carbon granules or by operating the MFC in full-loop mode. The latter option allowed reaching 99.7% acetate removal while generating a maximum power of $36\,\mathrm{W\,m^{-3}}$ at an acetate concentration of $2535\,\mathrm{mg\,L^{-1}}$. Under these conditions, the energy produced by the system averaged $0.1\,\mathrm{kWh\,m^{-3}}$ of wastewater treated.

13/03815 Perspective assessment of algae-based biofuel production using recycled nutrient sources: the case of Japan

Wang, T. *et al. Bioresource Technology*, 2013, 128, 688–696.

In this study, an upper limit in the solar energy conversion efficiency which can be translated to a maximum potential algal yield of a large-scale culture is calculated based on the algal productivity model in which light and nutrient are made the growth rate limiting factors, and taking the design characteristics of the cultivation system into account. The results indicate that for the production of low-cost biodiesel within the limits of the wastewater quality standards, that the culturing of high lipid content algae within a raceway pond would provide an appropriate solution for manufacturing biodiesel from algae. However, due to inefficient sunlight utilization and due to the large amount of fertilizer required in raceway ponds, a greater effluent recycle rate would have to be implemented to reduce the amount of fertilizer discharge to meet the wastewater quality standards and to maximize the attainable productivity of algal biomass.

13/03816 Process consideration of fry-drying combined with steam compression for efficient fuel production from sewage sludge

Hong, S. *et al. Applied Energy*, 2013, 103, 468–476.

The fry-drying and steam compression of wet sewage sludge were studied as part of efforts to enable the efficient production of fuel from wet sludge, the applicability of which requires energy-efficient drying. Fry-drying sludge in hot oil is fast and effective, while steam compressed to several bar enables the recovery of the latent heat of the steam evaporated from the sludge. The circulation of oil from the fry-drying bath to a steam condenser was examined as a medium of heat transfer for the absorption of the latent heat. The mass and energy flows through the process components were analysed in order to evaluate the effects of important design parameters. Optimal ranges of steam pressure and oil circulation rate were identified to maximize heat recovery while maintaining an appropriate oil temperature.

13/03817 Trace element behavior in the fluidized bed gasification of solid recovered fuels – a thermodynamic study

Konttinen, J. *et al. Fuel*, 2013, 106, 621–631.

Gasification of biomass and recycled fuels is of particular interest for the efficient production of power and heat. Trace elements present as impurities in the product gas should be removed very efficiently. The objective of this work has been to develop and test thermodynamic models for the reactions of trace elements with chlorine and sulfur in the gasification processes of recycled fuels. In particular, the chemical reactions of trace elements with main thermochemical conversion products, main ash components, and bed and sorbent material are implemented into the model. The possibilities of gas cleaning devices in condensing and removing the trace element compounds are studied by establishing the volatilization tendency of trace element compounds in reducing gases. The results obtained with the model are compared with the measured data of trace elements of gasification experiments using solid recovered fuel as feedstock. Some corresponding studies in the literature are also critically reviewed and compared. The observed discrepancies may be attributed to differences in thermodynamic databases applied and experimental arrangements. The method of removing gaseous trace elements by condensation is already in use in the 160 $\mathrm{MW_{th}}$ waste gasification plant in Lahti, Finland.